/10

Fracture of the tibia. Case illustrated by figure 139. Callus-formation two weeks after the injury. The anode was placed directly above the fractured area. The left leg was resting on the floor. The right leg was placed laterally, but, being supported, it was brought on a level with the anode. Thus it appears much the larger in proportion.

FRACTURES

BY

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WITH AN

APPENDIX

ON THE PRACTICAL USE OF THE RÖNTGEN RAYS

178 ILLUSTRATIONS

"Quidquid latet, adparebit,
Nil occultum remanebit."

PHILADELPHIA
W. B. SAUNDERS & COMPANY
1900

TO

Wilhelm Conrad Röntgen,

WITHOUT WHOSE DISCOVERY MUCH OF THIS BOOK COULD NOT HAVE BEEN WRITTEN.

PREFACE.

During the past few years literature on the Röntgen ray has grown to large proportions. It has led to many and revolutionizing discoveries; most of these have marked a clearer understanding, and consequently the better treatment, of fractures. Still, publications on this subject hitherto have not claimed to be more than tentative sketches or preliminary communications.

This book is an effort to encompass in a systematic treatise the important essentials of the publications on this subject and such individual studies and experience as it has fallen to my lot to make. In these studies the Röntgen ray has verified the anatomic findings. It did so by exposing the fractures in their living state.

The illustrations in older works were mainly made from the cadaver. The splendid schematic representations that resulted were not portraits from life. The minute arrangement and disarrangement of fragments and splinters, especially in their relations to the joints, were necessarily disarranged by even the most careful dissections. The Röntgen ray depicts these details and all others undisturbed and as they are in life. *It is with these that the surgeon has to deal.*

Before Röntgen's epoch-making discovery it was just and proper to associate all studies of fractures with those of dislocations. The essential aim of this association necessarily was for purposes of differential diagnosis. Now, however, the student, made familiar with the various types of fracture, has no difficulty in recognizing and appreciating the various forms of dislocation. Moreover, the greater importance of the former is evident in the fact that fractures occur no less than

ten times as frequently (a longer experience with the Röntgen ray will probably make it fifteen times) as do dislocations. Furthermore, the after-treatment of fractures must be predicated upon a thorough recognition of the anatomic relations of the line of solution of osseous continuity, while in dislocations the therapy after reduction is very simple. Necessarily, the differentiation of the more frequent luxations, that closely resemble fractures, has received considerable attention in these pages.

All the common, and some of the rarer, types of fracture are represented skiagraphically. The skiagrams and most of the drawings here presented are originals. They depict cases observed and treated in my dispensary, hospital, and private practice. Some illustrations are copied from Hoffa, von Bergmann, Ollier, Nélaton, and Lejars.

The skiagrams are exact reproductions of photographic prints. I resisted the temptation to emphasize their essential points by artistic interference, so that they represent the skiagraphic findings precisely as they are, with the exception of figures 107, 122, 151, and 169, in which the important points were lost during the process of reproduction. Figure 75 is treated schematically.

It affords me special pleasure to here thank Professor Röntgen for the many kindnesses of which I have been the recipient at his laboratory. My sincere acknowledgments are also due to Professors von Bergmann and Koerte, to Surgeon-General Stechow, of Berlin, and to Professors Hoffa and Gocht, of Würzburg, for many courtesies.

The skiagraphic plates were developed by Mr. Joseph Byron, whom I desire to thank for his painstaking work.

It also affords me pleasure to acknowledge my obligations to the publishers, W. B. Saunders & Company, for the typographic and pictorial excellence of this book.

CARL BECK.

37 East 31st Street, New York.

CONTENTS.

INTRODUCTION.

Few scientific discoveries of the century have astonished the world more than that reported by Wilhelm Conrad Röntgen, of Würzburg-on-the-Main. The significance of this great discovery can not even yet be estimated.

The preparatory researches that led to this discovery date from the time when Maxwell, extending and applying Faraday's theories, found that the phenomena of electricity depend upon the same principles as those of light. Both consist in vibrations of the ether that pervades the universe. Wiedemann, Verdet, Kundt, Gassiot, Spottiswoode, and Röntgen tried to prove that the phenomena of electricity are in close connection with those of light, and not only that electricity could produce light, but also that light could produce electricity.

The correctness of these theories, however, could not be proved until the experiments of Wilhelm Hertz, a professor at the University of Bonn, brought conviction to the minds of even the most skeptical. Hertz showed that electric induction obeys the same laws as those governing the diffusion of light-waves. He also determined the speed of transmission of the electric wave, which he found to be equal to that of the light-wave.

The phenomena of electric discharge in closed tubes, showing various degrees of exhaustion and filled with

different gases, had been the subject of experiment for many years, and a marked difference was noticed between the phenomena of light at the two electric poles. Light radiating from the positive pole extends entirely through a vacuum tube; while light radiating from the negative pole produces only a very weak and diffused illumination. But as soon as the vacuum is increased to a high degree, the phenomena become entirely different. The light of the positive pole decreases, while that of the negative pole pervades the vacuum more and more, being permanently propagated in straight lines.

The light emanating from the negative pole is called the "*cathode-ray*." Lenard and Hittorf found that such rays have the power of creating fluorescence, heat, etc., and that they can be deflected by a magnet. The vacuum-tube that is commonly used is generally called the Crookes tube, after Sir William Crookes, who described and slightly modified the tube. The credit for having originally devised it is due to Geissler, an ingenious mechanician of Bonn, Germany.

As soon as an electric current of high intensity goes through the conducting wires fused into the ends of the tube, the negative electrode, or cathode, becomes surrounded by a faint dark-blue light, while the positive electrode, the anode, sends a peach-colored light through the tube as far as the light of the cathode. As the air is gradually rarefied, the positive stream of light almost disappears, while the negative cathode light extends more and more, and finally fills the whole tube.

In December, 1895, Röntgen, while experimenting with these tubes by surrounding them with black pasteboard, impermeable by light, discovered an astonish-

ing phenomenon. On a screen standing near the tube, and painted with a light color (barium platinocyanid), he noticed a light as soon as an electric current went through the tube. It became evident at once that there was a radiant power that, although not perceptible to the eye, permeated the pasteboard. This force, heretofore unknown, also showed a marked effect on the screen. Röntgen, after having found that the effect of these invisible rays upon the screen was constant, tried photographic experiments also. He then discovered that under the influence of these rays his hand, resting upon the cover of a wooden box, gave a sharp silhouette on a drying plate below, although the cover was not removed. He also found that paper, wood, and even thin discs of metal, were permeable by the rays, while thick discs of metal, bones, etc., produced silhouettes. This latter discovery, in particular, at once aroused the most wide-spread interest in regard to its uses in surgery, and up to the present date its full significance can hardly be appreciated. Röntgen modestly suggested naming the new rays "X-rays," until their nature should be discovered; but Professor Kölliker, of Würzburg, very properly proposed calling them "Röntgen rays," and the veteran scientist's recommendation will probably be followed by men of science and by the profession.

The proofs of the great usefulness of the rays in surgery are now so overwhelming that to discuss them would be carrying owls to Athens. Their value in internal medicine has not as yet been made so apparent; still, much has been contributed in this field, and there can be no doubt that, with the better interpretation of the shadows and the continuous improvement of diagnostic technic, the significance of the rays in many of

the obscurer ailments will be convincing to the mind of the most skeptical.

The greatest usefulness of the rays thus far displayed is, however, in the recognition of *fractures*. *Accuracy takes the place of ignorance and doubt, and painful manipulations cease to be necessary for diagnostic purposes.* Even the most skilful experts in fractures are unable to deny that there is a large number of bone-injuries the character of which formerly could not be recognized, whether on account of the swelling of the area involved or from the obscurity of the symptoms. The number of cases of fracture formerly mistaken for contusion or distortion was enormous. It is in such cases that a simple glance with the fluoroscope furnishes the most precise evidence. Whether there is comminution or impaction or the intervention of muscular tissue or intra-articular fracture or combination with a dislocation, can be at once clearly determined. If the picture be fixed on a photographic plate, the nature of the injury can be studied at leisure, and the proper line of treatment easily decided upon without subjecting the patient to any tentative manipulations. After a dressing is applied, the skiagram verifies the proper position of the fragments. In fact, the proper execution of all therapeutic points can be verified throughout the course of treatment by the skiagram, the dressing itself, even if consisting of plaster-of-Paris, being no obstacle to the rays.

Even the shoemaker can profit by the rays, which will prove whether shoes fit accurately—an item of great importance in the after-treatment of fractures or in club-foot.

If the therapy proves to be imperfect, the rays show the nature of the condition. It is easily determined,

for instance, whether an ankylosis be fibrous or osseous; and, consequently, the question whether the breaking-up of adhesions or resection is indicated is settled at once.

It is needless to call attention to the frequent importance of a skiagraphic proof in court, for the protection of the surgeon as well as of the patient.

The greatest benefit obtained from the rays, in the proper judgment of the various types of fractures, is in connection with those situated in the neighborhood of joints. The special uses of the rays in diagnosticating the various types of fracture may be grouped as follows:

Fractures of the *clavicle* are, in general, easily recognized without the rays. Still, there are rare cases of infraction and fissure in which no deformity or crepitus is observable, and which could not be recognized except by the aid of the rays.

In fractures of the *scapula* the conditions are often so obscure that without skiagraphy the true nature of the injury may be veiled; for instance, when dislocation of the humerus is combined with fracture of the acromion.

In fractures of the *humerus* it is the shoulder-joint and elbow-joint that require the use of the rays most frequently. Especially in reference to the elbow-joint, it may be safely asserted that an exact diagnosis without skiagraphy is simply impossible in by far the great majority of cases. Skiagraphy will infallibly demonstrate the various types of elbow-fractures; it will, furthermore, show whether the line of fracture is transverse or T-shaped, and whether there are any complications, such, for instance, as a fracture of the olecranon combined with dislocation of the radius.

In fractures of the *forearm* it is the elbow-joint and the wrist-joint that especially require the use of these rays. In these cases as well as in those previously noted a large number of new facts have been revealed, which have entirely revolutionized our pathologic and therapeutic views.

Fractures of the bones of the *hand* occur much more frequently than was formerly supposed. Fractures of the individual carpal and metacarpal bones, and even of the phalanges, were often mistaken for contusions.

Fractures of the *pelvis*, the accurate recognition of which formerly offered the greatest difficulties, can also be readily demonstrated—the differentiation between contusion, fracture of the acetabulum or of the neck of the femur, and dislocation especially coming into question. Most valuable information can also be obtained as to the presence of impaction.

In fracture of the *femur* it is not only the hip-joint that may require the use of the rays, but also the shaft and the lower end of the bone. In the neighborhood of the knee-joint rapid swelling often absolutely prevents an accurate diagnosis except when the rays are employed. Furthermore, in all the different intra-articular complications the occurrence of epiphyseal separation, and the question as to the transverse or oblique or T-shaped line of fracture can easily be settled.

Fracture of the *patella* can easily be recognized without the aid of the rays. Still, there are some important questions—for instance, as to whether the fracture is complete or incomplete, or whether there are several fracture-lines—that could not be determined without the aid of the rays. It goes without saying that in the proper determination of the after-treatment, in the cor-

rect restoration of the fragments, and in the confirmation of the result in the event of wiring, skiagraphic control is simply indispensable.

In fracture of the *leg* the difficulties were often insuperable before the discovery of the rays. It is especially in the malleolar type that serious disturbances are observed. Especially in regard to the so-called Pott's fracture, many fresh facts were revealed by the rays, so that, just as in fracture of the lower end of the radius, our former views have been changed completely.

The number of fractures of the ankle treated as sprains and dislocations, to the great disadvantage of the patient as well as of the surgeon, is legion.

Fracture of the *foot* is also found to be more frequent than was formerly supposed. Individual fractures of the tarsal and metatarsal bones and of the phalanges were often erroneously taken for contusions. Stechow has found that the so-called edema of the foot, so frequently found among the German infantry, is always due to a badly united fracture of a metatarsal bone.

In fracture of the *ribs* and of the *sternum* skiagraphy will often prove to be useful from the standpoint of jurisprudence.

In fracture of the *vertebræ* the exact location of the fragments is of great importance in determining the advisability of operating.

In fractures of the *skull*, those of the face and of the inferior maxilla have derived the most benefit from the rays. Fractures of the base are still with difficulty demonstrated.

In fracture of the *larynx* the question of differentiation is easily settled by the rays.

PART I.

FRACTURES IN GENERAL.

CLASSIFICATION OF FRACTURES.

A fracture (a word derived from the Latin *frangere*, "to break") is a solution in the continuity of a bone. It is either *traumatic*—that is to say, produced by violence—or *spontaneous*, caused by disease.

Spontaneous fractures may occur on account of a *pathologic fragility* of the bones (osteopsathyrosis), which may be due to *tumors* (enchondroma, sarcoma, metastatic carcinoma, echinococcus cysts, etc.), or to *inflammatory processes* (caries, osteomyelitic necrosis, osteosarcoma, rachitis, etc.), or to *constitutional diseases*, such as syphilis and scurvy. Other cases are caused by *disturbances of nutrition of the bones*. Spinal diseases—syringomyelia, tabes—are also occasional causes.

In this book the traumatic fractures of healthy bones will alone be considered.

Traumatic fractures are either *direct* or *indirect*.

A *direct* fracture is one occurring at that point of the bone to which a force has been applied. It is obvious that this type bears a more serious character than one caused by indirect violence, since an injury

to the soft tissues covering the point of fracture is added.

An *indirect* fracture is one that occurs at a point distant from that where the force has been applied. A good example is a fracture of the lower end of the humerus produced by a fall upon the hand.

Sometimes a fracture is caused by *muscular contraction.* The seats of predilection for this variety are the olecranon, humerus, clavicle, os calcis, tibia, patella, and femur.

Traumatic fractures are also divided into *simple* and *compound.*

In *simple fractures* the bone is broken at one point, and no communication with the external air exists (*subcutaneous*).

In *compound fractures* the bone is broken at one or more points and communication with the external air exists.

According to the *degree of separation* in the continuity of the bone, distinction has also to be made between *complete* and *incomplete* fractures.

According to the *direction* of the fracture, *complete fractures* are either *transverse*, *oblique*, *longitudinal*, or *spiral.*

Thus, according to the *displacement* taking place after the fracture is sustained, four different types of a complete fracture may be noted: viz.—

1. *Lateral displacement*, characterized by the line of separation being at a *right angle to the long axis* of the bone (rare in adults). (Fig. 92.)

2. *Axial displacement*, in which the line of separation is at an *acute angle to the long axis.* (Fig. 89.)

3. *Longitudinal displacement*, when the separation-

line is *parallel to the long axis.* If there is axial displacement the so-called riding of the fragments takes place. It is often observed in fractures at the upper third of the femur. (Figs. 112, 114.)

4. *Peripheral displacement,* in which the fragment is *turned around the long axis of the bone* (torsion). (This variety may occur when the body is turned while the extremity is fixed.)

If in a complete fracture small bone-fragments are either partly or totally severed from the bone, it is called a *comminuted fracture.* (Fig. 136.)

If the bone is broken at several points, it becomes a *multiple fracture.* (Fig. 40.)

If a fragment consisting of compact bone is forced into the substance of a cancellated one, an *impacted fracture* is produced. (Fig. 107.)

If the fracture is caused by a bullet, it is called a *gunshot fracture.* The bullet of the army weapon known as the Kräg-Jörgensen rifle produces extensive splintering of the diaphysis of the long bones up to a distance of 800 yards. (Fig. 136.) This type of fracture may also be incomplete.

In *incomplete fractures,* which are mostly observed in very flexible bones, the convex corticalis yields and tears, while the concave stratum is only bent. This injury is called *infraction* (Figs. 92, 137); it may be compared to the bending and partial splintering of a green stick, and is mainly observed in childhood. Its predilection is for the deformed legs of rachitic children, but it may occur in old individuals, where senile atrophy has caused a diminution of the organic substance of the bones. It is also found, as a result of abnormal uterine contractions, as an *intrauterine* frac-

ture. There may be only a linear division, without any displacement or disfiguration of the external shape of the bone (*fissure*). (See Figs. 1 and 2.) This variety is

Fig. 1.—Intrauterine fracture of radius and ulna (outer view).

Fig. 2.—Intrauterine fracture of radius and ulna. Skiagram taken four weeks after birth.

observed in the cortex and at the base of the skull; in the superior maxilla and the scapula; seldom in the long bones.

STATISTICS.

Statistics show that fractures of the bones of the extremities, including those of the clavicle, represent three-fourths, while those of the bones of the trunk comprise but one-sixth, and those of the skull but one-twenty-fifth, of all fractures.

Fractures of the upper extremities are twice as frequent as those of the lower. Most frequent are the fractures of the forearm, 18 per cent.; then follow those of the leg, of the ribs, and of the clavicle, 15 per cent.; hand, 11 per cent.; humerus, 7 per cent.; femur, 6 per cent.; foot, 2.6 per cent.; face, 2.4 per cent.; skull, 1.4 per cent.; patella, 1.3 per cent.; scapula, spinal column, and pelvis, less than 1 per cent.; sternum, 0.1 per cent. Most fractures occur between the thirtieth and fortieth years. Fractures are four and a half times more frequent in men than in women.

SIGNS OF FRACTURES.

The symptoms of a fracture are represented by a chain of mechanical disturbances, set up by the solution of the continuity of the bone. The most important of these are abnormal mobility, crepitus, functional disability, deformity, ecchymosis, and pain.

1. **Abnormal mobility** is the most characteristic sign of the presence of a fracture. It is absent in the incomplete variety (fissures, infractions, etc.; see Figs. 92, 137), and also in impacted fractures—for example, in impacted fracture of the neck of the femur. (See Fig. 107.) In fractures of the ribs and the short bones unnatural mobility is also often looked for in vain.

2. **Crepitus** is the peculiar sensation felt when friction is caused between the two separated bone-fragments. Crepitus is, of course, absent when there is no abnormal mobility, since the production of the characteristic friction presupposes the mobility of the fragments. Consequently, also, there is no crepitus in

fissures and infractions (green-stick fractures), nor in impacted fractures. Crepitus is also absent in cases of the wide separation of the fragments, whether this be caused by diastasis (fracture of patella or olecranon), or by the interposition of fascia or muscular tissue between the displaced fragments. These circumstances will prevent mutual contact between the ends of the fragments. In other cases the fragments overlap each other to such an extent that contact between the broken ends is impossible (longitudinal displacement; compare p. 18), or sharp and displaced bone-fragments are driven into the muscular tissue, so that thus an interposition of soft tissues between the broken ends of the bones is produced.

3. **Functional disability** is seldom absent. Its extent naturally depends upon the shape and kind of the bone as well as of the fracture. This is shown in the cases illustrated by figures 72 and 123. There are individuals inured to pain who are able to use their arms notwithstanding the fracture of both radii, or who are able to walk a short distance in spite of having sustained a malleolar fracture; but such occurrences are to be regarded as very exceptional. Still, from a legal point of view the knowledge of such possibilities is of the utmost importance.

4. **Deformity** is present in those fractures wherein more or less displacement of the fragments has taken place. Consequently, it will not often occur in cases of fissure or in infractions; in other words, in fractures where neither abnormal mobility nor crepitus is to be found.

Thus it can be seen that the three important signs, *abnormal mobility, crepitus*, and *deformity*, usually go

together. It must be added that wherever deformity indicates more or less displacement, *shortening* of the broken bone is seldom missed.

5. **Ecchymosis** is naturally most marked in direct fractures. It is produced by the laceration of small blood-vessels and of the medulla of the bone. If the fracture extends into the joint, there is always an extravasation of blood within the joint (hemarthrosis). Ecchymosis is generally more marked a few days after the injury is sustained.

6. **Localized pain** is a constant symptom of fracture. It is increased by pressure and by every active or passive effort that displaces the fragments.

DIAGNOSIS.

In most cases the presence of a fracture can be recognized even by simple inspection. (Compare Fig. 33.) If the trifolium—abnormal mobility, crepitus, and displacement—is present, the proof of fracture is established beyond doubt. The value of inspection should not be underestimated. In fact, the part should be inspected very thoroughly before palpation is resorted to. The custom of handling an injured organ by pressing, turning, and squeezing before it is carefully looked at can not be condemned too strongly. It pays very well to inspect the injured area for some length of time, and to compare it with the normal outlines of the opposite side, until there is a clear idea of the condition of things in the examiner's mind.

But if there be an infraction or a fissure or an impacted fracture, or in cases where one of two parallel

bones is fractured (forearm, for instance; see Fig. 60), or if the break has occurred near a joint, or if there be extensive inflammation, the diagnosis may be very difficult, and the injury may be mistaken for a contusion or a distortion, or even a dislocation.

As to *dislocation*, it should be borne in mind that this injury does not lead to any abnormal mobility nor any shortening of the bone-shaft.

In *contusions* the absence of abnormal mobility, crepitus, displacement, and shortening will be observed. It is obvious that these differential points are mainly to be elicited by *manual examination*. This process being always productive of more or less pain, it should be performed with a great deal of care. While it is often possible to diagnosticate the presence of a fracture by means of careful palpation, conclusions as to its direction and as to the size of the broken fragments could seldom be drawn in the pre-Röntgenian era unless the patient was anesthetized. If there be abnormal mobility, manual examination will naturally yield crepitus also.

Whether or not there is shortening of the limb can be ascertained by *measurement*. It must be borne in mind, however, that the points from which measuring with a tape are begun fail to show mathematic exactness and regularity. They are represented by round-shaped bony protuberances, like the anterior superior spine of the ilium, the major trochanter or the external condyle of the femur, the external malleolus of the fibula, the styloid process of the radius, and the olecranon and acromion in the upper extremity.

This variation in position of the points of measurement explains why an error to the extent of a whole inch can easily be made. With the employment of all

these means, fractures have often failed to be correctly diagnosticated even by the greatest surgical masters of all centuries. The courts can show endless histories of grave errors committed to the detriment of poor patients and not the less of poor practitioners. But the discovery of Wilhelm Conrad Röntgen has come to do away with all this. At present there are no fractures the character of which can not be established beyond a doubt. But much more has been shown to us by these rays. A glance at the fluoroscope not only gives one an idea of the special type of the fracture, but the situation, shape, and the number of the fragments and their correlation can be clearly ascertained. The photographic plate fixes the details of the fracture exactly, and permits of the thorough study of the various features of the fracture type. Its comparison with the normal skeleton makes the abnormalities evident at once, so the use of anesthetics, which in many cases are not at all advantageous for the patient's physical condition, is no longer required in diagnosis. It is clearly seen that the advent of the Röntgen rays has accomplished no less than a revolution in the understanding of fractures. On account of their special importance, the diagnostic use of skiagraphy is considered in a separate section.

THE PROCESS OF REPAIR AND THE FORMATION OF CALLUS.

Repair of simple subcutaneous fractures generally takes place without any constitutional disturbance. The course being an aseptic one, fever, as a rule, is absent. When there is much extravasation, infiltration, or destruction of tissue, the lively absorption of blood-ferment may cause slight and transient elevation of temperature (up to 101.5° F.) (*aseptic absorption-fever*).

Microscopic examination of the urine shows, with few exceptions, for the first four or five days following the injury, cylindric elements, brownish clots, and the relics of shrunken blood-corpuscles. Traces of albumin are also often found in the urine. Fat is absorbed from the shattered medulla of the bone by the lymph-vessels, and gains access thereby to the blood-circulation, from which it is generally excreted slowly without causing any disturbance. In the urine its presence is also not infrequently demonstrated. In cases of extensive shattering, however, or in multiple fractures, an abundance of fat accumulated in the circulation is sometimes caused, which may lead to *fat embolism*. In this extremely grave condition, which is nearly always fatal, there is in the capillaries a conflux of fat-globules, which causes the obstruction of numerous capillary channels by cylindric masses of fat. This occurs especially in the lungs. The blood-vessels that are incarcerated between these masses are compelled by pressure to give their serum away to the lung tissue, so that edema of the lungs is produced.

The symptoms of this condition are those of shock ;

they never appear as a primary shock occurring immediately after the injury was sustained, but manifest themselves, as a rule, on the third, or sometimes even on the fourth or fifth, day. Owing to the edematous condition of the lungs, dyspnea, combined with cardiac irregularity, naturally is a prominent symptom.

The *swelling* of the soft tissues in the immediate vicinity of the fracture is caused by extravasation and edema, the latter being produced by a slight degree of inflammation. The swelling generally disappears by absorption in the course of the first week. The integument, which had been overextended by the swelling, becomes flabby, and at the same time loses its original bluish-black discoloration and shows the characteristic rainbow tints.

Formation of Callus.—Hand in hand with the absorption process goes the formation of a new bone-tissue, called *callus*, which originates between and around the broken ends and gradually fills up the separation line, thus restoring the continuity of the broken bone.

Most of the callus is formed from the inner strata of the periosteum, while the medullary tissue furnishes the rest. The first indication of the healing process is the occurrence of a periosteal swelling (*periostitis ossificans*), which is caused by the proliferation of the osteoblastic cells, between which lime-salts are deposited. (Fig. 3.) Lacerated portions of the periosteum are scattered around the fracture area and form another starting-point for peripheral growth. The processes of cell-proliferation and calcification of the young tissue begins simultaneously from the medullary canal and Haversian channels. Afterward

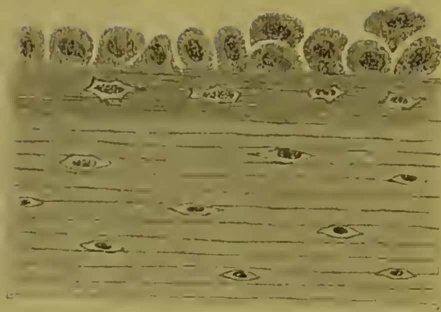

Fig. 3.—Osteoblasts on old bone.

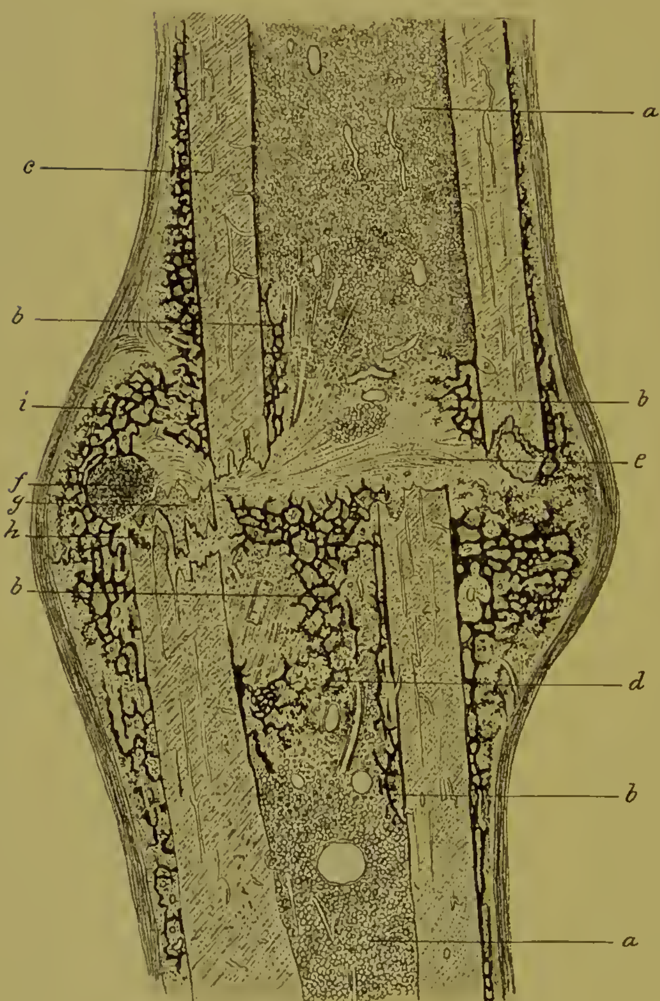

Fig. 4.—Longitudinal section through a fractured fibula in a young adult (two weeks after the injury): *a*, Fatty medulla; *b*, myelogenous bone-trabeculæ; *c*, corticalis; *d*, myelogenous trabeculæ, consisting of osteoblasts and osteoid tissue; *e*, connective tissue between the fragments; *f*, newly formed cartilage; *g*, fragment separated from the fibula; *h*, osteoblasts; *i*, periosteal osteophytes.

the periosteal and medullary calluses join within the separation line, so that the bone-ends are surrounded exteriorly by a broad ring, while interiorly, or within the medullary canal, they are fastened by a plug of young bone-tissue. (Fig. 4.) A conception of the progress of this formation can be gained by palpation, which reveals a spindle-shaped thickening of a slightly cartilaginous character around the line of bone separation. (Compare Fig. 113.) A few weeks after the injury, when the formation of the external ring (periosteal callus) and of the internal plug (medullary callus) is completed, the periosteal swelling subsides also, the callus becomes solid, and mobility ceases to be observable.

The length of time necessary for perfect consolidation varies between two and twelve weeks, according to the size of the bones. From the statistics of E. Gurlt it is learned that perfect consolidation of complete subcutaneous fractures requires for—

Metacarpal or metatarsal bones, as well as ribs	3	weeks.
Clavicle	4	"
Forearm	5	"
Humerus and fibula	6	"
Surgical necks of humerus, and tibia	7	"
Tibia and fibula together	8	"
Femur	10	"
Neck of femur	12	"

For some time after this complete consolidation has taken place the anatomic condition of the callus by no means remains unchanged. Years may elapse before the original callus-tissue is completely absorbed and the regular bone-system with the normal medullary canal is reestablished, as is easily proved by the Röntgen rays. According to the degree of displace-

ment there is abundant callus proliferation, so that sometimes enormous masses are thrown out, and may be mistaken for regular osteomas. In children, in whom there is frequently but little periosteal laceration, there is sometimes so little callus formation that even the Röntgen rays disclose but a very thin line of separation. In such cases the evidence of a fracture may not be proved by the rays two months after the injury was sustained. (Fig. 137.)

Since aseptic treatment has brought the mortality of *compound fracture* from 45 per cent. down to nearly *nil*, the consolidation of fragments in this condition, formerly so much dreaded, generally takes place without inflammatory reaction, or with very little.

Even in pre-antiseptic times such consolidation was occasionally observed in one class of compound fractures: namely, gunshot wounds.

In compound fractures *necrosis* of one or both bone-ends sometimes occurs. This is caused by the detachment of periosteum, so that the vascular supply is diminished. A line of demarcation usually forms between the normal and the necrosed tissue; and in between two and six months after this the necrotic bone exfoliates. Meanwhile the ossifying inflammation of the periosteum creates abundant bone-substance, so that enough material for thorough consolidation is furnished.

Sometimes callus formation is *late*. Among all fractures, that of the upper third of the humerus shows the greatest tendency for late union. The cause for this condition can but seldom be elicited. Syphilis, scurvy, rickets, malignant bone-disease, and paralysis are generally held responsible for it.

DISTURBANCES IN THE PROCESS OF REPAIR.

One of the most distressing disturbances in the healing process of fractured bones is the failure of the occurrence of bony union between the broken ends, the consequence of which is the formation of a new false joint (**pseudarthrosis**). Pseudarthrosis is either called *fibrous*, in which case the only junction between the fragments consists of fibrous tissue, or *real*, when there is the formation of a true joint-capsule, the latter condition being extremely rare. (Fig. 135.) Exceptionally, however, a synovial membrane and synovia are formed. It is self-evident that in either event, whether there follows either a fibrous or a true pseudarthrosis, the bone-ends remain movable.

The *causes* of false mobility may be either *local* or *constitutional*. Late necrosis of the callus, caused by inflammation and suppurative infection from a focus (furuncle, tonsillitis), even in simple subcutaneous fractures, and especially in the extensive crushing of the broken area, so often produced by compound fractures, favors its formation. Scant callus formation, which, as before stated, often delays union, may also be responsible for pseudarthrosis.

Interposition of soft tissues (muscle, fascia, and tendon) produces pseudarthrosis with absolute certainty. This intervention is most frequently observed in the humerus and the femur, a fact which is explained by the great tendency to extensive displacement manifested in these long bones. In these cases thick masses of surrounding muscle are easily pushed between the fragments. As before mentioned, overrid-

ing of the fragments may produce pseudarthrosis, even if there be profuse callus formation.

The *constitutional causes* favoring non-union are the same as those that cause late union. Pseudarthrosis takes place in about 1 in 400 fracture cases.

Gangrene may be the result of a *mechanical* or of a *traumatic* cause. The application of too tight a splint is a well-known and most deplorable mechanical cause of gangrene. Extensive pulping or laceration of soft tissues or the rupture of a large blood-vessel, often caused by a crush or by sharp bone-fragments, may lead to extensive blood-extravasation, which is liable to result in gangrene. It hardly needs to be stated that these lesions are of a severe character. The anterior and posterior tibial arteries are those most frequently observed to become ruptured in this manner.

The same causes may sometimes produce **aneurysm.**

A mechanical insult to a *nerve* situated at the point of a fracture may also lead to a series of complications. There may be a direct injury done to a nerve, as, for instance, to the radial or peroneal nerve; or a perforation by a bone-splinter (interposition of the nerve) of the nerve that rests directly upon the bone. (Fig. 66.) In other cases pressure conveyed to the nerve by exuberant callus proliferation (Fig. 67) produces loss of *sensation* or *motion*, or of both. If the paralytic symptoms appear slowly and gradually, it may be regarded as an absolute pathognomonic sign that the nerve-pressure is due to exuberant callus formation.

Embolism and **thrombosis** are very rare occurrences in subcutaneous fractures. These conditions are mostly observed in fractures of the bones of the

lower extremity. Their cause is the formation of a blood-clot, induced by the trauma of a vein. From the clot obstructing the vein (thrombosis) an embolus may originate, which, after being torn away, may reach the pulmonary artery; and sudden death may follow the plugging of this artery. The signs that foretell this fatal occurrence are sudden suffocation, cyanosis, dyspnea, and an imperceptible pulse. There are, however, a few cases on record in which, in spite of the marked development of the clinical symptoms of this grave condition, recovery has taken place.

Ankylosis (from ἀγκύλος, "angular, crooked") may be *bony* or *fibrous*. Bony ankylosis may be originated by a direct fracture into a joint, followed by an inflammatory process, which in the course of time unites the bone-fragments among themselves within the joint. (See Fig. 118.)

Fibrous ankylosis may be caused by an inflammatory process in the joint. This may have been produced by some condition such as a profuse hemorrhage into the joint, leading to synovitis or arthritis, from which *adhesions* within the joint may follow. Hematoma, if not absorbed, may also lead to serous or purulent tenosynovitis. If plastic inflammation is set up in the sheath of a tendon in the vicinity of a joint, stiffness of the joint may result (tenogenous ankylosis). This is especially observed in non-reduced fractures of the lower end of the radius.

Prolonged immobilization also sometimes produces mild forms of fibrous ankylosis.

Atrophy is nearly always caused by prolonged inactivity of the muscles. But, in the course of time, it will affect not only the muscles, but also the tendons. Just

as a sword becomes so rusty in its scabbard that it can not be drawn, so may a tendon become adherent to its sheath, if it be not frequently moved to and fro. Motion induces the secretion of the synovia in the tendon-sheath and thereby keeps up the possibility of the smooth gliding of the tendon therein.

Delirium tremens is a not infrequent and often a fatal complication. It is characterized by the violent inclinations of the patient, the presence of delusions, and the entire absence of fever. An alcoholic history will but seldom be absent.

Pneumonia is provoked by prolonged dorsal decubitus (hypostatic), and is especially apt to occur in alcoholics and old patients.

In summing up it can readily be seen that if the causes of the disturbances in the process of repair be analyzed thoroughly, it will be found that, except in a few cases, the ill results specified can be avoided by carefully controlling the course of a fracture. Since asepsis began its triumphant march the evil consequences of even compound fractures have been reduced to a minimum. (Compare p. 51.) Life is generally only endangered nowadays when organs of vital importance, such as the brain, spine, lungs, or pelvic viscera, are injured.

TREATMENT.

The laws that govern the treatment of fractures are determined by a correct diagnosis. In fact, the principles of treatment are reduced to a few points of simple common sense as soon as there is a complete and correct diagnosis.

Simple subcutaneous fractures showing but little or no displacement often heal without any, or in spite of any, treatment, as the long sin-register of quackery demonstrates; and the number of fractures not recognized as such during treatment is legion.

The first object of a rational therapy is the consolidation of the fractured ends without any displacement and without injuring the adjacent tissues or the function of the limb. It is evident that if there is no *dis*placement, no *re*placement (or, better said, no reposition) will be necessary. All that is required then is to protect the injured limb in its normal position. This is done by proper immobilization.

In the great majority of cases, however, more or less displacement of fragments follows the fracture. In such an event, of course, the displaced fragments must be reduced to their normal position. After *exact reposition* has been attained, *proper fixation* in the normal position is in order.

These doctrines are so simple that it seems almost unnecessary to repeat them. And yet they are violated frequently. The functional impairment following some fractures, especially the formation of adhesions in the vicinity of joints, has led a number of surgeons to enunciate this dogma: "The most important part in the treatment of fracture is the treatment of the soft tissues." They claim, in other words, that because the function of the soft tissues—for instance, of the tendons—is impaired after a non-reduced fracture, the soft tissues should have received more attention, instead of the displaced fragment having simply been reduced to where it belongs. Nothing, in fact, is more contrary to common sense than this dangerous maxim,

which is based upon correct observation, but incorrect interpretation. It should always be considered that the relations of the soft tissues to the bones are like that of the clinging vine to the sturdy oak.

Galen says that the bones give the human body form, erectness, and firmness. It is evident that an injury of the bones impairs these three fundamental factors. The most important step toward repair must thus be taken in the foundations rather than in the superimposed structure.

If there is displacement of the bone-fragments, undue pressure must necessarily be made upon the soft tissues ; *non-reduction means persistence of pressure*, the fatal consequences of which are well known. *Reduction means the relief of pressure.* Of course, the act of injury can not be undone by the mere cessation of pressure ; but the influence of the injury on the soft tissues—the influence of the pressure, in fact—lasts only a short time and is insignificant after early reduction ; there is then but little inflammation, and consequently little exudation, and therefore repair is easy. This means that the premises of adhesion-formation are wanting. And clinical observation shows that if there was perfect reposition, the joints as well as the sheaths of the tendons are found free, provided the immobilization has not lasted for an extraordinary length of time.

To accomplish exact reposition, it is desirable to have the assistance of one or two persons, who should make extensive counterextension while the surgeon replaces the displaced fragments. In fractures of the bones of the upper extremity assistance can be dispensed with, but in those of the lower extremity proper reposition is hardly possible without the assist-

ance of at least one person. If the exact situation of the fragments has been ascertained (and this can always be done), the surgeon should know at once how to replace them to their former—that is, to their normal—position. This is done by making manipulations either in the way of pressing sideward and turning one of the fragments, or by putting the limb into a proper angle, and thus correcting the abnormal direction.

Whenever the fragments can be seized by the surgeon's fingers reduction will be found easy; but if their manipulation is difficult, anesthesia is to be employed. If the surgeon is undecided as to whether he should administer an anesthetic, he should give the benefit of the doubt to the anesthesia. Reduction is especially difficult where there is extensive displacement of the fragments, or if their sharp edges have pierced the soft tissues, or if muscular tissue intervenes, or in the rare event of simultaneous dislocation. But all these conditions can easily be ascertained by the Röntgen rays, and under their guidance reposition will always be successful.

If a fracture has been sustained in the street, some kind of improvised splint should be applied, and no reduction should be tried before the patient has reached his home; but as soon as he has arrived there, reposition should be undertaken at once, since the whole course of recovery might be jeopardized by delaying this most important procedure.

If the upper extremity is concerned, the surgeon may seize each fragment with one hand, and by pulling and counterpulling the fragments are slowly put into their normal position.

In fractures of the bones of the lower extremity the patient should be placed upon a firm bed. Clothing, shoes, etc., in the vicinity of the fracture should be cut off, to avoid any unnecessary manipulation of the broken area. The limb must be carefully lifted, constant extension being exercised at the same time.

The pelvis must be immobilized, which is best accomplished by one assistant putting his hands on the crests of the ilia and pressing the pelvis down upon a tight underlayer; or the pelvis may be drawn upward by slinging a long towel around the perineum. The surgeon should now seize the patient's foot on the heel with his left and on the metatarsus with his right hand, while he pulls. When he has lifted the foot to the horizontal position, the fragments are carefully turned to and fro, according to the direction of the displacement, until the tip of the foot, the interior margin of the patella, and the anterior superior spine of the os ilii are in a straight line.

If two assistants can be obtained, they can make extensive counterextension, and the surgeon may then reduce the displaced fragments by simply pushing them into their proper positions.

If extravasation be exceptionally profuse, *puncturing* or *massage treatment* should be employed until it becomes possible to grasp and reduce the displaced fragments. (As to the technic of puncture, see the section on the Treatment of Patellar Fracture.)

After reposition is accomplished, immobilization of the reduced fragments must be secured in order to retain them in their proper place. For this purpose the broken bone-ends as well as the adjoining joints must be surrounded with suitable apparatus in the

shape of splints and bandages. If nothing else be at hand, shutters, pillows, or similar improvised contrivances may be utilized.

On the battle-field bayonets, sabers and their scabbards, muskets, etc., may serve as temporary splints.

The thorax may act as a splint for a broken arm, if necessary, the arm being fixed upon it. In like manner a broken leg may be fixed upon the sound one.

Fixed Dressings.—As soon as reposition has been perfected, *fixed dressings* (splints, plaster-of-Paris, etc.) should be employed for the purpose of retaining the fragments in their proper positions. In case complete reduction can not be accomplished at once, *extension dressings* are preferable.

All fixed dressings require an underlayer, consisting of cotton, flannel, or muslin, in order to avoid pressure upon the swollen area and at the same time to prevent the hairs of the skin from adhering to the dressing.

It is a matter of skill and experience to apply a dressing tight enough to render shifting of the fragments impossible, and, on the other hand, to apply it so smoothly that there is no pressure. Gangrene of that portion of the skin resting directly upon a bone-protuberance is easily produced even by a moderate amount of pressure. It is wise, therefore, to pad such dangerous areas profusely.

Venous stasis and edema, finally leading to necrosis, may be caused by too tight an application of a simple bandage. To avoid such possibilities it is advisable, in all fixed dressings, to leave fingers and toes always uncovered, so as to have permanent control.

No dressing accomplishes the purpose of retaining

the fragments better than *plaster-of-Paris*, since it adapts itself to the contours of the body in an admirable manner, and surrounds it at the same time like a coat of mail. The best quality is not too good for use in a surgical dressing. The extra-calcined variety ($CaSO_4 2H_2O$), such as is used by dentists, is considered the best. Good plaster must set quickly and firmly; in fact, it must become hard in about a minute after the dressing is complete.

In making plaster-of-Paris bandages the following points should be observed: The plaster-of-Paris is dusted over a crinoline bandage about five yards long and from two to four inches wide. The bandage is best laid upon a table and the plaster rubbed well into its meshes, where it is evenly distributed. After thorough impregnation it is rolled up loosely and stored in an air-tight can until needed.

When used, the plaster bandage is immersed in lukewarm water until bubbles cease to come up, which fact announces its being thoroughly soaked. Then the bandage is squeezed out well and evenly and is firmly applied. Reverses must be avoided. To give the dressing a nice appearance, some dry plaster may be moistened well with water until the consistence of thick cream is obtained. This paste is then evenly rubbed over the surface of the dressing.

If there are small wounds present that require an aseptic dressing, a small opening (fenestra) should be made over them. If they are covered with a small glass or bottle or ointment-pot while the bandages are being applied, these points can easily be kept open. (Fig. 5.) The fenestral margins are best surrounded by absorbent cotton, which may be fastened to the integu-

ment by collodion. At the knees, the groin, etc., it is necessary to strengthen the fenestral margins by laying small wooden splints so as to prevent breakage of the dressing.

To preserve the plaster dressing against moisture (a femoral dressing in a child will surely be destroyed if

Fig. 5.—Fenestrated plaster-of-Paris dressing (for wound-treatment).

moistened with urine), it should be painted with copal varnish. (See Fig. 115.)

The taking-off of a plaster dressing is generally more troublesome than its application. The best instrument for the purpose is a circular saw provided with a beak. If this instrument is not at hand, a grooved line, into which salt water or, preferably, vinegar is poured, is scratched into the plaster. This will facilitate cutting through the plaster layer alongside this marked line.

During the last few years—thanks to the impetus of Hessing, the ingenious mechanician—the application of plaster dressings, especially to the lower extremity, immediately after the fracture is sustained has been highly recommended by F. Krause, Korsch, Albers, and others. (Fig. 6.) In many instances the patients have been permitted to go about after an interval of a day or two.

Ambulatory Dressing.—The advantages of this ambulatory dressing are obvious. Atrophy of the muscles is surely avoided, as their functions are not interrupted. Late union or non-union does not occur, if this method is employed, since callus formation is abundant. Hypostatic pneumonia, so dangerous in aged people, is absolutely excluded. There is also much less tendency to delirium tremens. It hardly needs to be mentioned that this form of treatment adds considerably to the patient's comfort.

In supramalleolar fracture, or that of the head of the tibia and the femoral condyles, and in fractures of the femur, the pelvis may serve as a point of support. The sole portion of the dressing is made especially strong, to permit of stepping upon it. At first the patients are allowed to move only in a go-cart.

But these advantages are fairly offset by the immense difficulty in keeping the treatment under permanent control in practice. The technic of applying such dressings is complicated, and therefore is dangerous in the hands of the inexperienced. In hospital practice, where continuous control is possible, the adoption of this method in many instances proves to be of great value.

So, while this treatment is undoubtedly advisable in cases in which the dressing can be removed any

moment, in case ischemic symptoms should manifest themselves, it should not be recommended for adoption in general practice. Proper individualization, based on sound judgment and experience, should

Fig. 6.—Ambulatory dressing.

fix the limits to its applicability. Here, as in many other instances, the golden mean should be chosen. The writer has often found it useful to permit his patients to walk about as soon as the swelling had

subsided, under the protection of a well-padded and carefully applied plaster-of-Paris dressing.

In the hospital service of the writer this stage was generally reached after the elapse of a week. Sometimes slight edema was set up at first; then the patient was directed to lie down at once, and his lower extremity was vertically suspended until the swelling had disappeared. In private practice it is not advisable to start the patient to walking before at least two weeks have elapsed.

When a circular plaster-of-Paris dressing is applied, it will often be found desirable to utilize it as a splint after carefully taking it off. In these cases the underlayer of the dressings should consist of muslin only, and the bandages should be applied as firmly as possible. As soon as hardened, the dressing is cut through alongside a straight line, which has previously been marked with a pencil. To avoid injury of the skin while cutting the dressing, it is advisable to protect the area below the mark with strips of pasteboard or of thin board. After the dressing is carefully removed, it can be lined with tricot and provided with strips.

Molded plaster splints can be made of bunches of hemp, flax, jute, or straw that have been immersed in a thin paste of plaster. After being soaked there the fibers are applied to the part, where they are held by the turns of a wet bandage. The part has first to be protected by oiling. (Figs. 7, 8, and 9.)

These removable splints are particularly serviceable in the treatment of compound fractures. (See p. 67.)

A special splint of this kind, most useful in fractures of the humerus, is the *collar splint* (Fig. 7), which is

made by rolling the plaster bandages up and down in a longitudinal direction, covering the metacarpus, the dorsum of the hand, and the extensor portion of the arm to the shoulder and the middle of the neck. About eight bandage strips are required for this purpose. When the layers are thick enough, the neck portion is reversed outwardly. Thus a support is gained for a bandage, which runs from this improvised collar down to the axilla of the opposite side. In

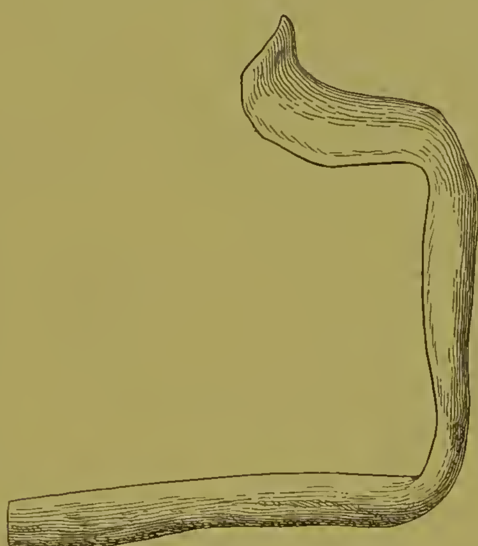

Fig. 7.—Collar splint.

the same manner the splint is fastened to the arm. (Fig. 8.)

If *suspension* of a limb in a splint should be considered, hooks or loops of wire may be inserted. (Fig. 9.)

The *interrupted plaster-of-Paris dressing*, in pre-antiseptic times so very much *en vogue*, is almost entirely abandoned now, since wound dressings nowadays need to be changed but rarely. It is only in cases of sepsis and joint suppuration that they are

used, in order to permit of frequent changes of the wound dressing without causing the patient much discomfort. In this method of dressing the wound area is overbridged on two sides by a strong rod of iron, the straight ends of which are incorporated in the

Fig. 8.—Collar splint superficially fastened in fracture of the humerus.

plaster-of Paris dressing, while bent loops leave the wound area free for the application of the wound dressing.

As a substitute for plaster-of-Paris, *silicate of potassium* is sometimes used (so-called *sodium dressing*). Its advantages are its cheapness and lightness; its

disadvantage is that it requires twenty-four hours for becoming dry and firm. This forbids its application in fractures of recent origin, but in a later stage its employment may well be considered. The manner of application is very simple. The silicate of potassium mixture having been poured into a basin, a number of circular bandages are well soaked in it. Then the bandages are put upon the limb after the same principles as are observed in applying plaster-of-Paris dressings. A muslin underlayer must be applied first in order to protect the integument.

The only disadvantage of the plaster-of-Paris dressing is that if a swelling sets in underneath, the arterial

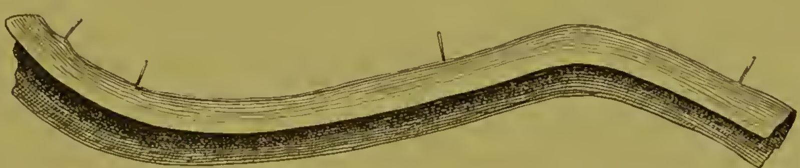

Fig. 9.—Molded plaster splint for the lower extremity, ready for suspension.

supply becomes limited, and the muscles lose their elasticity, and may consequently become contracted (ischemic contraction). Nerves may be injured in the same way, ischemic paralysis being then the consequence. Under strict hospital control such outcome need not be feared, since the dressing can be cut off as soon as the first signs of swelling are noticed. But most fractures are treated outside of the hospital, where the surgeon must rely principally upon the initiative of the patient. The most unfortunate feature of such accidents is that the stronger the pressure becomes, the more the sensation stops, so that the patient is then under the fatal impression that his con-

dition has improved, and the necessary surgical interference is liable to be unduly postponed. It is much safer, therefore, at least for the surgical novice, to apply splints at first,—that is, during the first week after the injury,—and then, after the swelling has almost subsided, to substitute a plaster-of-Paris dressing.

The number of the different *splints* advised for the treatment of fractures is legion. There is hardly a surgeon of repute who has not devised a splint or splints of his own. Most of them are useful, but under the ægis of a thorough diagnosis one is surprised to find how much he can accomplish by choosing the simplest forms of splints. The limits of this book forbid describing more than a few kinds. A splint consisting of simple board in most cases is just as good as any other. If lime-wood (linden or bass) can be procured, it should be preferred for this purpose. A splint should be well padded with muslin or flannel and should extend over the joint nearest the fracture on each side just the same as the plaster-of-Paris dressing. A dressing of this kind should also be changed at least once a week. When, after the elapse of a week, the swelling has subsided, the dressing becomes loose, and the fragments may easily become displaced again.

Wire splints (Fig. 12), besides having the great advantage of being made of a light and clean material, adapt themselves easily to the contours of the body. They are especially useful in the treatment of compound fractures. (See p. 67.)

The fiber splints, recently advised by Wiener, furnish a very convenient material, and the splints made of *gutta-percha*, *porous* or *hatters' felt*, *leather*, *cellulose*, or *pasteboard* are also serviceable.

Permanent extension, best known as *Buck's extension*, is a simple and valuable means of keeping the fragments *in situ* so as to overcome shortening. It is particularly used in fractures of the femur and the spine, sometimes also in fractures of the surgical neck of the humerus and of the elbow. Extension and counterextension are exerted by the use of a weight and a pulley, the counterextension being made by elevating the foot of the bed. (Fig. 10.) The weight must

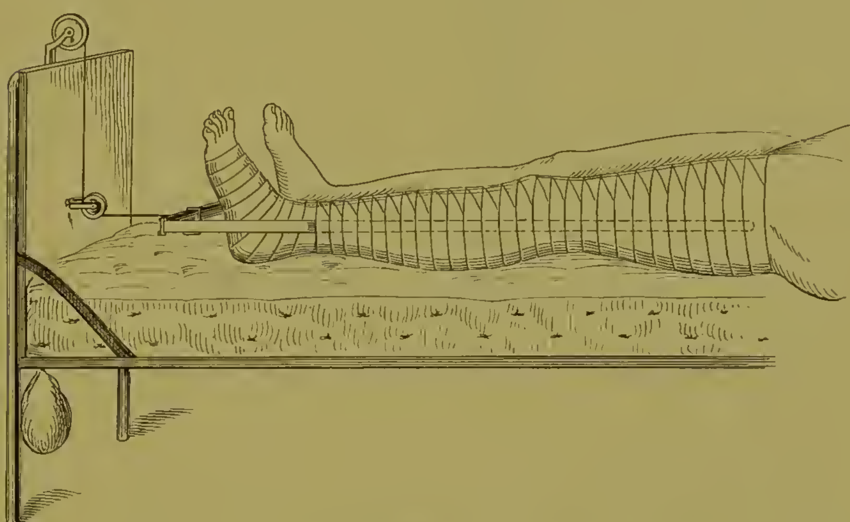

Fig. 10.—Extension dressing in fracture of the femur.

be the heavier the older the individual and the greater the muscular rigidity is. It may vary from five to twenty-five pounds. If a light weight be used, the patient will stand the treatment better and longer; but if too little weight is employed, the fragments are likely to become displaced. The weight is suspended by a loop made of adhesive plaster strips, which should extend up to the fractured area. In fractures of the femur a wide adhesive plaster strip should reach as far up as to the

knee-joint, to take off the strain from the latter as well as to arrest motion. In order to keep the plaster off both malleoli, a board is inserted between the two adhesive plaster strips for the purpose of keeping them far asunder, so as to avoid decubitus. (Fig. 11).

In order to obtain perfect immobilization of the lower leg and at the same time to avoid decubitus, Volkmann devised his so-called foot-board. (Fig. 11.)

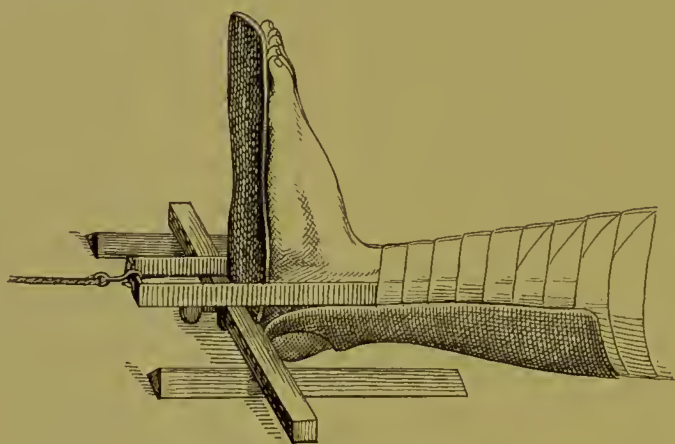

Fig. 11.—Volkmann's foot-board.

If the adhesive plaster is not well borne, a filtrated sticking substance can be sprayed over the limb by an atomizer.* Two felt strips of the width of a hand are applied in a longitudinal direction. They are fastened by circular turns of a mull bandage. To the lower ends of these felt strips a canvas strip is attached to serve as the loop for the weight.

* A commendable sticking mass of this kind is:

℞.	Ceræ flavæ, Resinæ Dammara, Colophonii,	āā 10	parts.
	Terebinth,	1.01	parts.
	Ol. Terebinthinæ, Alcohol, Ether,	āā 55	parts.

Massage is a splendid adjunct in the after-treatment of fractures. If there is no tendency to displacement,—as, for instance, in the extraarticular variety of partial fracture of the lower end of the radius,—or if small portions of the condyles are broken but still remain in contact with the bone, or if, in fracture of the patella or the olecranon, no diastasis is present, massage treatment can be commenced as early as a few days after the injury. But whenever there is the slightest tendency to displacement, this treatment is not in order before thorough consolidation of the fragments is warranted.

To substitute massage entirely for the good old immobilization-treatment, as has been advocated recently, is not advisable.

There has lately been observable a tendency on the part of a few surgeons to treat simple subcutaneous fractures by **wiring the fragments.** While under the auspices of asepsis such treatment need not be followed by any reaction, and might in the hands of competent masters give excellent results in suitable cases, such tendencies must be regarded as surgical aberrations. It is only where much diastasis is present, as in fracture of the patella (olecranon), when bony union appears improbable, that such rigorous interference is demanded. But by our recent means of making a positive diagnosis possible in all cases it is usually just as easy to obtain a perfect result by a simple bloodless reduction and by thorough immobilization.

Compound fractures have to be treated according to the principles of the aseptic wound treatment.*

* Compare the author's "Manual on Surgical Asepsis," chap. II; W. B. Saunders, Philadelphia.

To understand asepsis we must, first of all, know the factors which may interfere with its thorough execution. They are: The instruments, the dressing and suture material on the one hand, and, on the other, the atmosphere and the skin of the patient and of the surgeon's hands. In reference to the first factors it can safely be maintained that ideal asepsis is now an established fact. All objects which stand boiling well can indisputably be made sterile. This also applies to the much-disputed question of catgut, since Hofmeister has shown us by the formalin treatment how to boil this material without impairing its tensile strength.

It is, of course, to be presumed that the sterilization of the material in question is supervised by the surgeon himself. The process of sterilization must, in other words, go on in the operating room, where the sterilizers must be kept. There the towels, dressings, the suture material, etc., must be taken from the sterilizer and put directly upon the instrument table or the body of the patient. This naturally causes trouble for the surgeon, but it is an absolute necessity, in view of that fatal human characteristic—forgetfulness.

The second factor, the atmosphere, seemed to have been settled by the classic experiments of Schimmelbusch, Petri, and Cleves-Symmer. But in consequence of Fluegge's investigations* this question has been revived recently, and it seems to have disturbed the surgical mind unnecessarily. Theoretically, the possibility of atmospheric infection can not be disputed; but it hardly is attainable in practice. The atmosphere, it is true, contains an enormous number of bacteria, but these being innocent mold, yeast, and fission fungi,

* Fluegge, "Zeitschrift für Hygiene," 1897, Band xxv.

they are, fortunately, nonpathogenic for the human race. Bacteria which are pathogenic for man are present in the atmosphere only under abnormal conditions: as, for example, when they are stirred up from their natural habitat—the earth's surface or the dust of the walls, the floor, the tables, etc. The properties of the atmosphere are, in fact, injurious to pathogenic bacteria in every respect. The atmosphere, if exceptionally visited by a vagabond pathogenic bacterium, can be only a temporary and most uncongenial halting-place for it, in which it will soon be destroyed. It is a most fortunate feature of the pathogenic bacteria, especially the pus-producing variety, that they have a marked tendency to settle. Wherever they settle they adhere, and if they are not provoked, so to say, by being stirred up, they can not come into contact with a wound any more.

According to Stern's experiments, heavy bacteria settle to the ground within the course of an hour and a half, while the lighter ones require about an hour longer.

From these facts we learn that the bacteria-containing dust in a room should not be stirred up by cleaning and sweeping a few hours before an operation is to take place there. As moisture precipitates dust, it is advisable to saturate the air in the operating room at least during two hours before the operation. This can be done by filling the air with spray or with steam from a kettle. The windows should also be kept closed, especially if there is a current of wind directed toward them.

But another possible source of infection propagated by the atmosphere deserves attention. The air ex-

pired by the healthy, according to Tyndall, does not contain bacteria, although the cavity of the mouth is a well-known gathering-place for all kinds of pathogenic as well as nonpathogenic bacteria. Staphylococci and streptococci are nearly always found. It has, however, been proved by bacteriologic tests that in healthy persons the virulence of these bacteria is very slight. Clinical observation is in accord with this. But if the surgeon suffers from tonsillitis or even from a rhinitis, the number as well as the virulence of his intra-oral bacteria is remarkably increased. If the sick surgeon talks and coughs a great deal while bent over the wound, there is a possibility of carrying some of these bacteria into it, especially in an operation of long duration. The remedy is simple, and proves the wisdom of the old saying, "Speech is silver and silence is gold."

The assistants in the operating room must be so well drilled that they understand a twinkle. Most manipulations can be carried out as by an automatic apparatus, without the need of saying one word. Still, if the surgeon is very scrupulous, he would best stop performing important operations until his recovery from the ailments I have mentioned.

Easy as the maintenance of asepsis is in regard to the atmosphere and to all objects which stand boiling, so is it difficult in regard to the skin of the patient and the hands of the surgeon. Skin-bacteria are the stumbling-block in the way of perfect asepsis. The undeniable fact remains, that their total destruction or removal is practically impossible.

The surface of the human body is impregnated with many different bacterial species. Some of them adhere to the skin surface, some are embedded in the dried

cells of the epidermis. They are all accessible to sterilization. They do not necessarily need destruction, but removal. This can be done by simple mechanical means—viz., scrubbing with soap and water. It is made so much the easier by preliminary procedures—viz., whenever possible, the patient is given a warm bath twenty-four hours before operation, the field of operation being scrubbed with green soap and shaved while the patient is in the bath. Then a poultice of ordinary green soap is applied to the skin until shortly before the operation. Thus, thorough permeation of the epidermis—the dried cells of which are, in fact, macerated by this procedure—is obtained. Areas like the perineum, and the scrotal and inguinal regions, which are particularly rich in glands, must be scrubbed with especial care. Before the operation the skin is scrubbed energetically with linen compresses which are dipped into hard fluid soap. This hard soap consists of green soap mixed with soft sand (Stuttgart sand). The scrubbing process consumes about two minutes' time, and goes on while a stream of very warm water constantly flows over the surface to be sterilized. Then thin green soap is used in the same manner and for the same length of time. Particular attention is given to the folds and creases of the skin. Now the skin is dried with an aseptic towel, and rubbed for one minute with a gauze compress which is saturated with fifty per cent. alcohol. The alcohol is not regarded as a disinfectant in the proper sense, but it is mainly used for the purpose of dissolving the fat of the skin, which is a most congenial resting-place for bacteria. By dissolving their shelter the bacteria are naturally removed.

It is self-understood that the means with which asepsis should be attained must be aseptic. This refers particularly to the water used for washing and the soap, which must have been prepared by the boiling process. If brushes are used, special care has to be taken, as they can only with difficulty be rendered aseptic, thorough cleaning impairing their usefulness.

Whether after these procedures washing with bichlorid of mercury or lysol or similar disinfectants is still needed is open to discussion; it will certainly do no harm.

There are other similar methods of rendering the surface of the skin sterile. If they are thoroughly mastered and carried out minutely, they may be employed just as well; but the trouble is that underneath the skin surface a number of bacteria are sheltered by the glands of the skin, the secretions of which offer a favorable soil for their development; and these are not accessible to any disinfection or removal. Hence, other means have to be chosen to prevent their faculty of infection. And, in fact, they will do little harm if cared for properly.

It is evident that in incising the skin the knife dissects a number of glands and thereby exposes the bacteria contained by these glands. This undeniable fact fully explains not only the so-called suppuration of the stitch-canals, many cases of so-called late infection, and the bad reputation of the catgut, but also most of the numerous "incomprehensible" infections which develop under the supervision of the "extremely careful aseptic surgeon." Here is also the explanation of the suppuration occurring "in spite of the most minute aseptic precautions," which not only

astonished many an experimenter in his laboratory, but also made him set up new surgical doctrines.

I may take this opportunity to state that bacteriologic tests of aseptic methods, gained on artificial soil, can not be applied to biologic processes, the living cell reacting against bacteria differently from gelatin, agar, or serum.

That the *bacteria thus set free by the skin incision find the most liberal opportunities to come into contact with the deeper regions of the wound* need not be emphasized. Still, so far as my knowledge goes, there are no systematic precautions taken or advised in this direction. If a general can not fight the enemy successfully in the open battle-field, he tries to starve him out, or he may eventually overreach or circumvent him. And the deep-skin bacteria can also be circumvented.

Let us consider, now, that the dissecting knife coming into intimate contact with these deep-skin bacteria, generally represented by the staphylococcus species, must necessarily be regarded as infected. The hands of the surgeon fall under the same considerations. This indicates two necessities—in the first place the change of the infected knife, and secondly the redisinfection of the surgeon's hands. The latter procedure may become unnecessary if gloves are worn by the surgeon while the skin is being incised.

One possibility, however, remains—inoculation of the subcutaneous strata with the knife. This danger can not be obviated entirely, but it can be reduced to a minimum by slowly and carefully incising the integuments alone as far as possible.

Now, as to the exposed skin-bacteria which can not

be destroyed or removed: how easy is it to set them *hors de combat* by simple *protection!* Sterile napkins are fastened to the subcutaneous tissues with miniature forceps, such as devised by the author, so that the skin margins are so well covered by them that they do not come into view during all the subsequent manipulations, which are done then on an absolutely sterile field.

After the operation is completed the margins should be united by the subcutaneous method. If there is an absolute necessity for relaxation sutures, they should be applied through the skin, but about three-quarters of an inch distant from the wound margin, so that there is no direct contact with the wound-line. For such sutures, however, iodoform silk should be chosen. The same principle of protection should, under proper modifications, be employed in the opening of deep-seated abscesses. This principle was emphasized by the author before, in connection with the operation for pyothorax, in a paper read before the German Medical Society of New York in 1887. Then the author had tried to protect the fresh wound margins with iodoform-ether or collodion, before he had opened the pleural cavity, in order to prevent infection from the outflowing pus. Very little attention is paid to this point, as is evident from the custom of incising abcesses like appendicial pus accumulations, intraosseous pus foci, etc.

Once in a while the so-called disposition to infection is also spoken of. There is something in the theory, but only in a modified way. What favorable conditions are, for instance, offered by the skin of a working-man? And still, under the most aggravating circumstances, infection is but seldom found among this

class in general, while among the so-called better classes the most virulent forms of infection are observed, sometimes after a slight abrasion of the skin. This undeniable fact can not be explained simply by the difference of bacterial species or the degree of virulence. The explanation must be founded on biologic grounds. It seems that the plebeian cell in the strongly developed fist of a laborer resists, by virtue of its greater vitality, the fiercest enemy of mankind more energetically than the aristocratic one in the little-exercised hand of a man of leisure. On the other hand, there are a few members of the laboring class who show a most striking tendency for virulent infections—a fact which can be explained by the peculiar action of chemic influences. It certainly makes some difference whether bacteria are introduced into the cell in a pure state or whether they are suspended in a greasy vehicle. The cell that is able to defend itself against the naked bacterium, so to say, may be powerless against one suspended in dirty machine oil.

The principles of sterilization of the surgeon's hands are practically the same as those governing sterilization of the skin of the patient. The only essential difference is, that the surgeon's hands do not need to be incised, wherefore the deep bacteria of the skin of his hand are not exposed, provided that there are no forcible efforts made to dislodge them and squeeze them out, so to speak. This would, indeed, be provoked only by brutal manipulations on the part of the surgeon.

The author has repeatedly seen surgeons who had taken scrupulous care in their aseptic preparations

handle the intestine in the roughest manner, permitting it to come into contact with the abdominal skin and its wound margins, while manipulating the intestine after it had been taken from the abdomen for inspection. It speaks highly for the natural powers of defense of the human body, that in spite of such manipulations infection does not take place in every such instance.

The same *modus operandi* holds good for the sterilization of the surgeon's hands, minus the preliminary preparations. The length of time necessary for the scrubbing of the surgeon's hands may vary according to whether the surgeon had come in contact with septic cases shortly before sterilization or whether he was positive that he had remained clean for at least the last twenty-four hours.

Furthermore, the most particular care must be given to the subungual space. Wicked tongues remark of certain physicians that they carry graveyards underneath their finger-nails. To clean the subungual space a Braatz's nail-cleaner is advisable. The nails must be cut short and even with scissors, not trimmed with a file. The space is then scrubbed—first with the rough soap, and then with the alcohol water.

It hardly needs mentioning that the surgeon should wash himself frequently, like other decent people, whether he perform an operation just at the time or not. In order to protect himself as much as possible he should wear rubber gloves when coming in contact with notorious bacterial shelters, such as the rectum, or when examining septic cases. He should also wash with especial care after an operation.

However, to reduce the possibility of infection communicated from deep-skin bacteria, gloves are advis-

able. Their use was highly recommended by the author as early as in March, 1895, in his manual on "The Theory and Technique of Surgical Asepsis" (Saunders, Philadelphia), page 94. It is true that the gloves sometimes interfere with the technic of a delicate operation; sometimes, however, they permit of easier handling—as, for instance, in intestinal work. Cotton gloves offer no insurance against the action of bacteria, but they act as a kind of filter bag, or as a bacteria trap, in which bacteria are not killed but arrested. When gloves are not worn, it must be remembered that the hands of the surgeon should come into contact with the wounded area as little as possible. Most manipulations can and must be done with instruments, which are always indisputably sterile after being boiled. So, for instance, a needle-holder should be used while sewing, instead of taking the needle in the hand; thumb-forceps should be used for holding tissues, instead of securing them with the fingers.

Erratic bacteria which are not pressed into the wound may perish, while in the midst of heaps of crushed cells they may develop in number and virulence. Thus may be explained why some surgeons who perform the dreaded operation of wiring patellar fracture without touching the wound surfaces with anything but instruments show splendid results, while the experience of others has been so sad that they have given up the operation on account of the "exceptionally great danger of infection."

These considerations bring us near another most delicate question—namely, the surgeon's manual dexterity. Since the advent of the aseptic era it seems to be supposed by many that this has become an unneces-

sary accomplishment. Under the auspices of asepsis countless technical sins are committed with a light animus. Some are under the impression, for instance, that if they only stick to the letter of aseptic rules they do not need to care for a minute approximation —as, for instance, of the gut after resection. But in the event of the slightest diastasis the most thorough aseptic precautions prove to be valueless in such a case; and, on the other hand, the invasion of a few bacteria might have done little harm if the approximation was done with great technical skill. How else could the miraculous results of some surgeons of the preantiseptic times be explained? The author need refer only to his distinguished teacher, Bernhard von Langenbeck, the results of whose plastic operations astonished the world. And his classic rules for plastic operations were outlined long before the days of antisepsis.

Whoever saw von Langenbeck operate must have had the impression that he was an aristocrat in the best sense of the word. He had a most pronounced sense for natural cleanliness. It was not customary at his clinic to wear sterile gowns before the introduction of antiseptic rules, but the students wondered why the master, while operating, always wore a long, peculiarly made Prince Albert coat, which fitted high over the neck. This coat was always cleaned very thoroughly, sometimes to the disappointment of the operating nurse. There was a great contrast to the nonesthetic customs at other clinics of the same period. The hands were frequently washed, and the instruments, sponges, and the ligature material were kept extremely clean. Von Langenbeck's technic was that of an artist.

His work was as delicate as a watchmaker's. His anatomic knowledge enabled him to make his skin incision in conformity with the deep seat of the lesion which indicated the operation. Naturally, he could also carry out his steps rapidly. Thus, by the short duration of his operation he exposed his patient to a smaller risk of infection. His gentle handling of the tissues in general, his aversion to blunt operating, his predilection for sharp and clean instruments, were all points which counterbalanced to a certain degree the preantiseptic shortcomings. Such accomplishments should by no means be regarded as unimportant in this modern era. The surgeon should strive zealously to come as near to such perfection as possible.

Thus we can see that the success of aseptic surgery does not depend upon a few principles, but that it is the happy combination of scientific knowledge, conscience, and manual skill which makes the surgical master, who must thoroughly understand and regulate the thousandfold different wheels of that wonderful organic clockwork—man.

If we translate our considerations now into practice, the following maxims will result:

1. The superficial surface of the skin of the patient and of the surgeon's hands is sterilized after the principles set forth above. The atmosphere being innocuous, all inorganic material being made aseptic by boiling, the skin surface being ascepticized, and the skin-glands that contain bacteria being *hors de combat*, it becomes evident that the only possible source of infection remaining would be rough manipulation on the part of the surgeon or of his assistants.

2. Aseptic gloves are worn by the operating surgeon

at least during the skin incision. The assistant who passes the instruments and the one who attends to the wound itself wear gloves throughout the whole operation.

3. After incision the wound margins of the skin are covered with sterile napkins, which are fastened to the wound surface underneath the skin margins with miniature forceps, so that the skin wound is not touched at all during the subsequent manipulations.

4. The knife used for the skin incision must not be used for further incisions. The operation should be performed as rapidly as possible.

5. For uniting the wound margins of the skin the subcutaneous method should be preferred.

6. Forcible manipulations, especially blunt operating, should be avoided. Hemostasis must be very thorough.

7. The surgeon and assistants wear sterilized suits or gowns. Their heads must be covered with sterilized caps, because in bending over the field of operation it often happens that the heads of the surgeon and his assistant come in contact, whereby infectious material might be introduced into the wound.

8. Long beards are entirely unsurgical.

9. If a surgeon should suffer from rhinitis, tonsillitis, etc., he should use the most minute local precautions, or would better omit operating until recovery. It is self-understood that a surgeon should regard it as a crime to operate as long as he suffers even from a slight furuncle on his hand.

With the expenditure of a little more time and trouble the same principles can be carried through in private practice also.

In case of shock hypodermic saline infusions should be made.

Whether a compound fracture is *a priori* infected or not can hardly be proved. The state of a compound fracture may with some probability be regarded as aseptic if the person who sustained it and the wounding object were both clean, and if but little time had elapsed before it came under the observation of a surgeon. Still, whether aseptic or not, the principles of prophylactic disinfection and the carrying-out of the disinfecting process remain the same, as previously described. (See p. 52.)

If there should be but a small wound, the surfaces of which will agglutinate before infection is possible, union by first intention is often secured, provided the premises of secondary infection are removed by the prophylactic disinfection. The further course of such fractures does not differ from that of a simple subcutaneous fracture.

But if there is extensive injury to the soft tissues, splintering of bones, perforation into a joint, etc., a large incision should be made. An attempt should always be made to first locate the splinters by the Röntgen rays. The loose splinters must be extracted, while those that still maintain an attachment to the periosteum should be left. Fragments of fat, muscular shreds, fascia or crushed skin, and other debris should also be removed. Projecting points of bone should be trimmed off with bone-forceps. If the bone-fragments show much tendency to displacement, they should be wired or nailed together. (See technic of wiring, p. 69.)

All hemorrhage must be carefully arrested; foreign

bodies—such as splinters of wood, glass, and bullets—are to be extracted. Pockets underneath the integument are split wide open. These manipulations should be performed only while irrigation with a 0.1 per cent. sublimate solution is maintained. If necessary, counteropenings are to be made, so as to permit the introduction of thorough drainage. Great care must be taken that the drains do not come between the bone-fragments. It is inadvisable to apply sutures to wounds of this kind. After small rubber drains, surrounded by iodoform gauze, are introduced into the counteropenings, the wound cavity, especially the pockets, is extensively packed with iodoform gauze. The wound is further protected with a large amount of some sterile and absorbent material. The most desirable substance for this purpose is *moss-board*, made of common German moss, the absorbent power of which is five times as great as that of gauze. It represents a very soft and adaptable material, and it can be very easily sterilized. It is used best by being compressed into a tablet-like shape. (Fig. 23.) It can also be used loose, after being put into gauze bags, but it then loses its most convenient property—its immobilization power. The moss-board, after being dipped into cold water, adapts itself to the contours of the body like a plaster-of-Paris splint, over which it possesses the great advantages of being absorbent and much lighter. (Fig. 23.) The bulky species of moss-board makes an ideal splint; for, should the wound discharge exceed the absorbent power of the gauze directly over the wound, it takes up the superfluous discharge without impairing the usefulness of the moss as an immobilizing factor. To make a moss splint adaptable

it must be dipped into, and not soaked in, cold water. If warm water is taken, the moss will swell up rapidly and the immobilization power is lost. If the secretion becomes abundant, the center of the moss-board, by absorbing it, swells up naturally, but there is so large a portion of the molded moss splint left that its value as an immobilizing apparatus does not become impaired, any more than does a plaster-of-Paris dressing by the cutting of a fenestra.

Immobilization will be so much the more reliable if a large *wire splint* is adapted besides.* (Fig. 12.)

In case there is an indication for antiseptic lotions the wire splint does not conflict with their application. If this splint, after being boiled and loosely

Fig. 12.—Simple wire splint.

covered with sterilized gauze, is adjusted by a gauze bandage, it represents an absolutely sterile and permeable material. Putrid cavities are packed with some antiseptic gauze (iodoform gauze); besides, a strong antiseptic drug should exercise a continuous influence. This will be accomplished if a strong bichlorid solution is poured on the gauze dressing, which is thus kept permanently moist, the bichlorid solution coming continuously into direct contact with the wound surface. Accordingly, in well granulating wounds the dry treatment (iodoform gauze, moss splint, and over this the wire splint) should be preferred. But if there be a putrid cavity, the moist method (iodoform

* See the author's "Manual on Asepsis," p. 200.

gauze packing and padded wire splint only) should be selected. For small wounds, provided there are good granulations, a fenestrated circular plaster-of-Paris dressing may be used and the wound may be treated through the fenestra. (Compare Fig. 5.) The same method may be selected when large wounds which have formerly had a putrid character have lost their virulence under the influence of a moist antiseptic dressing.

Under this treatment many cases heal that formerly were destined to amputation. Still, there are cases in which the soft tissues are so extensively destroyed that conservative treatment may fail of success. In some cases there may be such extensive crushing and splintering that, from the very beginning, the preservation of the limb is out of the question, and amputation has to be resorted to. Such an extreme course fortunately represents at present but a small percentage of cases. Nowadays the surgeon should amputate only after having considered all the pros and cons most carefully.

During the treatment of a compound fracture the patient has to be observed thoroughly. Great stress must be laid on taking the morning and evening temperature regularly.

As far as the change of the dressings in compound fractures is concerned, the tendency at present is to disturb them as rarely as possible. The main indications for change of dressing are:

1. When stitches or drainage-tubes require removal.
2. When secondary hemorrhage occurs.
3. When the discharge becomes so abundant that it can not be absorbed by the dressings, and a consequent transudation to the surface takes place.

4. When the dressing has been so disturbed or moved that either the protection of the wound becomes imperfect or there is risk of contamination by urine, feces, etc.

5. When the patient complains of intense pain.

6. When fever sets in and general symptoms point toward infection.

7. When there is any doubt as to the character of the fever.

In case of *non-union* the fragments must be sutured together with silver wire (Fig. 13 *a*) or very stout catgut. To accomplish this, holes are bored near the ends of the fragments with a strong drill. Through these holes the suture material is drawn, and the fragments are then pulled together. Greater security of adaptation is obtained by resecting the bone-ends in a staircase-like shape. (Fig. 13 *b*.)

Good approximation may also be obtained by using long, four-cornered, well-polished nails, with which the fragments are nailed together. The nails must project to the extent of nearly an inch beyond the level of the integument. Steel is the best material for nails, and should be preferred to ivory; not only because steel nails can easily be rendered sterile by boiling, but because they can be extracted much more easily, while the ivory pegs become so decalcified after a little while by the carbonic acid in the tissues that they become rough and their extraction is thereby made difficult.

Instead of nailing the fragments together, *insertion* of an ivory peg into the medullary cavity of the fragments may be employed.

Implantation is another ingenious method. It consists in pointing the thinnest of the two fragments, so

that it can be inserted into the medullary cavity of the other and larger fragment. (Fig. 13 *c*.)

Simple fractures may exceptionally be converted into compound fractures on account of great muscular spasm, from necrosis of a small fragment, or from the different sources of infection. The writer has observed three cases of suppuration in simple fractures of the femur, the subjects of which were boys of four, five,

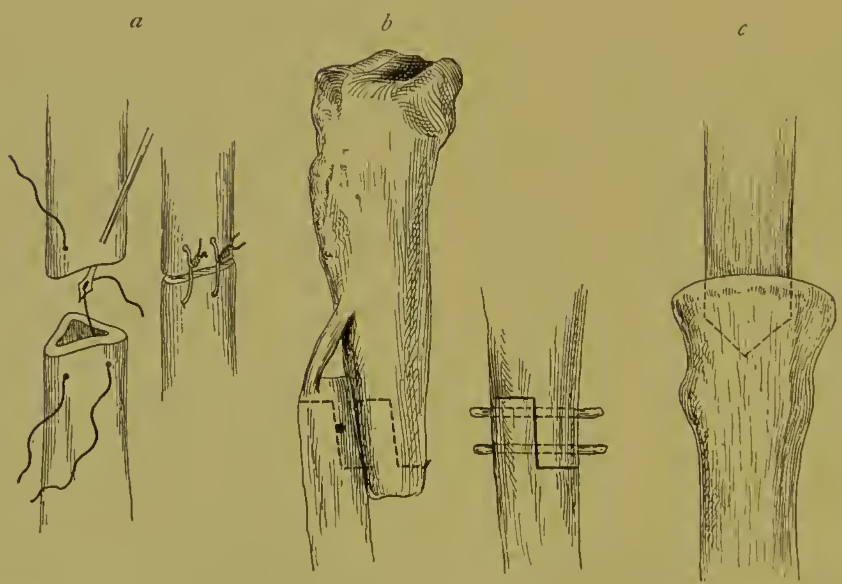

Fig. 13.—*a*, Bone-suture; *b*, staircase-shaped exsection; *c*, implantation of bone-ends.

and seven years. They all suffered from tubercular inflammation of the adjacent knee-joint, the suppuration setting in between the second and third week after the accident. Free incision becomes imperative in such cases; after which treatment will be the same as before advised. (See p. 65.)

Treatment of Disturbances in the Process of Repair.—In discussing this subject we shall do best to follow up the instances given under the heading

Disturbances in the Process of Repair (p. 31), where the causes and consequences of these disturbances are discussed.

Pseudarthrosis is sometimes successfully treated by electrolysis. Nailing the bones together with ivory pegs is naturally more effective. But the safest way is *resection*. The ends of the fragments should be freshened and then sewed together with silver wire (Fig. 13 *a*) or stout catgut, as described on page 69. If there is much tendency to displacement, the ends may be resected in the form of steps, in order to make them fit closer. (Fig. 13 *b*.) The insertion of a pointed bone-end into the medullary cavity of the other fragment may also be considered. (Fig. 13 *c*.) In light cases energetically rubbing the ends of the bones together daily sometimes sets up so much local reaction that callus formation is induced. The production of moderate venous hyperemia by the use of a rubber tourniquet is also recommended. The same procedure may be used in cases of late union.

Gangrene has to be treated after the principles set forth on page 68.

Aneurysm has to be treated after general surgical principles.

Compression of a nerve may be relieved by exposing it freely; a wide incision being necessary if the nerve should be surrounded by much callus proliferation, which latter should be chiseled away. After such interference perfect recovery has been observed in a number of cases. (Figs. 66, 67.)

Embolism has to be treated after general medical principles, stimulation of the heart being the main factor (digitalis, caffein).

Ankylosis offers but poor chances for complete restitution. The bony variety (compare Fig. 118) requires osteotomy, combined with the exsection of a bone-wedge. In fibrous ankylosis repeated forcible motion and manual correction of the abnormal position under anesthesia sometimes yield fair results, provided much time has not elapsed since the injury was sustained. Massage treatment is also a potent factor.

But the most good can be done by early prophylaxis. If a fracture is situated in the vicinity of a joint, so that ankylosis is to be feared, the latter will certainly be avoided, if massage and active and passive motion are employed as soon as the swelling has subsided.

Delirium tremens must be treated mainly by prophylactic measures. Alcohol (wine, whisky) should be given in moderate quantities to such individuals as are accustomed to its use. A light diet should be observed. Opium and chloral in large doses may be freely administered. Patients who give an alcoholic history should be induced to walk about as early as possible. (See p. 42.)

Pneumonia is treated after general medical principles. The main factor in this connection is also prophylaxis. Aged persons especially must walk about as soon as possible. If in bed, their positions must frequently be changed. In fractures of the lower extremity, if walking in a plaster-of-Paris dressing (compare Fig. 6) should prove to be inopportune, extension should be employed when aged people are concerned. When patients of advanced years can not be allowed to walk it is best to let them sit up in bed as much as possible, in order to prevent circulatory stasis and its train of evil consequences.

PECULIARITIES OF FRACTURES IN CHILDREN.

Although fractures in children must practically be considered from the same standpoint as those in adults, they present some characteristic deviations, which deserve a special description.

Among the more marked varieties of infantile fractures the intrauterine and congenital and the rickety and spontaneous types may be mentioned. Almost peculiar to infancy and childhood are separation of the epiphysis and the so-called "greenstick" fracture. (Fig. 90.) It may be added that the scapula, sternum, and pelvis are but seldom fractured in childhood, while the clavicle, humerus, radius, thigh, and leg are more frequently involved than in adults. Fractures of the fingers, the skull, and the maxillas are also much rarer in childhood.

In *intrauterine fractures* (see Figs. 1, 2, and 93) normal union takes place in a large number of cases. Sometimes there is no union at all, and often a greater or lesser degree of deformity is observed.

Congenital fractures are of moderate frequency. For detailed description see Part II.

True *epiphyseal separation*—that is to say, a real chondro-epiphyseal division (Fig. 50), where the epiphyseal cartilage is sharply severed from the osseous end of the diaphysis—occurs in infants only, and is extremely rare, while osteo-epiphyseal separation (Fig. 49) is frequently observed between the ages of fourteen and seventeen. In these latter cases the fracture line is not limited to the epiphyseal cartilage, but extends to the diaphysis. Traumatic separation has a

marked predilection for the epiphyses of the upper and lower ends of the humerus, the lower end of the radius, and the lower ends of femur and tibia.

The different epiphyses naturally show a tendency to separation at various times. The dates of ossification and union of the epiphyses of the humerus, radius, femur, and tibia are, according to Quain:

In the *humerus* the nucleus of the head appears in the second, of the capitellum in the third, of the internal condyle in the fifth, of the trochlea in the eleventh, and of the external condyle in the fourteenth year (see Fig. 174), while union between the lower epiphysis and the diaphysis takes place between the sixteenth and eighteenth years, and between the upper epiphysis and the diaphysis in the twentieth year. The lower epiphysis of the humerus consists of four nuclei, which ossify and unite between the eighth and eighteenth years, a fact that is of great importance in the correct interpretation of skiagraphs. In the *radius* (see Fig. 87) the nucleus of the lower end appears at the end of the second year, while that of the head follows at the fifth. The upper epiphysis and the diaphysis unite between the seventeenth and eighteenth years, and the lower epiphysis and diaphysis join in the twentieth year. The nucleus of the lower end of the *femur* (see Fig. 138) appears as early as at the ninth month, while that of the head shows at the end of the first year. The head unites with the diaphysis at the eighteenth or nineteenth year, and the lower epiphysis follows after the twentieth year. The upper epiphysis of the *tibia* (see Fig. 138) appears at the time of birth, while the lower one shows in the second year. The lower tibial epiphysis unites with the diaphysis between the eighteenth and the nineteenth

years, while the upper epiphysis unites with the diaphysis in the twentieth or twenty-second year. The Röntgen rays, however, enabled the writer to observe the well-marked cartilaginous condition of the lower tibial epiphysis and a distinct epiphyseal line in a healthy man of twenty-four years. In dwarfs the epiphysis may remain cartilaginous up to the fortieth year.

The **symptoms** are the same as those of the corresponding fractures in adults. A most unpleasant feature of epiphyseal separation is the tendency to premature ossification, which leaves a stunted limb.

In *rickets* (an infantile disease so frequent in Europe, and, thanks to its prosperity, very rare in this country) the bones are brittle, in spite of their containing an abundant proportion of animal matter ; so they are therefore very liable to break in consequence of even a small degree of violence. The greatest tendency to such fracture is shown by the clavicle and femur.

Fragility in scurvy and in infantile paralysis of long standing are also well known. From clinical observation the writer has received the impression that the presence of tuberculosis of the knee-joint also predisposes to fragility of the femur in childhood.

It is but natural that the *subjective symptoms* of fracture in a child should differ somewhat from those of analogous injuries in adults. Particularly the inability to call attention to pain and to the site of fracture must be considered in very young children. The author has, for instance, observed cases of infantile supramalleolar fracture where objective symptoms, especially displacement and deformity, were absent, while the subjective symptoms present pointed toward an injury of the hip-joint—a mistake which was cleared up only after dis-

coloration of the supramalleolar integument called attention to it. It must also be borne in mind that in children the pain of a fracture is less intense than in adults, and that in many cases it is even insignificant. (See p. 81.) If non-ossified tissues, such as the area of an epiphysis, are concerned, or if, as often happens in childhood, the periosteum has remained intact, other valuable signs—displacement, deformity, and crepitus—will naturally be absent. In fact, the line of fracture in some cases is so indistinct that it is difficult to fix it, even on a plate made by the Röntgen rays. (See Fig. 137.) The deformity caused by a greenstick fracture is often so slight that it may easily escape notice. These unpleasant features of infantile fractures are somewhat atoned for by their agreeable property of tending in most cases to rapid and almost certain union, a property which is due to the active formative process in the infantile bone and to the abundance of the callus production. These facts explain the rare occurrence of deformities as well as of non-union in childhood.

Non-union occasionally occurs in fractures sustained *in utero* or shortly after birth, and especially in cases of necrosis of the humerus and the tibia. (See Figs. 134, 135.) There is a decided influence upon the trophic nerves in this disturbance, probably due to a subtle derangement of the anterior horn of the spinal cord, in consequence of which the nutrition of the bone is inhibited. Consequently the bone is rendered weak and friable and its repair is hindered.

The principles of **treatment** are identical with those applying for adults. Epiphyseal separation must also be treated according to the same rules. In children

the plaster-of-Paris dressing can be used to a much greater extent than in adults. (See p. 34, on treatment.) As to detailed rules, see Part II, on Fractures of Special Regions.

PART II.

FRACTURES OF SPECIAL REGIONS.

FRACTURES OF THE SHOULDER AND UPPER EXTREMITY.

CLAVICLE.

Fracture of the clavicle comprises sixteen per cent. of all fractures. It is caused either by direct violence—such as blows and falls—or by transmission of the impulse of a fall upon the shoulder or the extended arm. The longitudinal axis of this bone, which is interposed between scapula and sternum like a buttress, becomes compressed to a certain extent, and must break at the point of its least resistance. This is generally located between its medial and external thirds, the bone being least in diameter there. (Fig. 14.) Fractures of the sternal and acromial ends are rather uncommon.

While rare in the aged, fracture of the clavicle is extremely frequent in childhood. The character of the fracture is generally simple. In children infractions are also frequently met with. Sometimes in children the sternal extremity is torn off.

Symptoms.—The symptoms of fracture of the

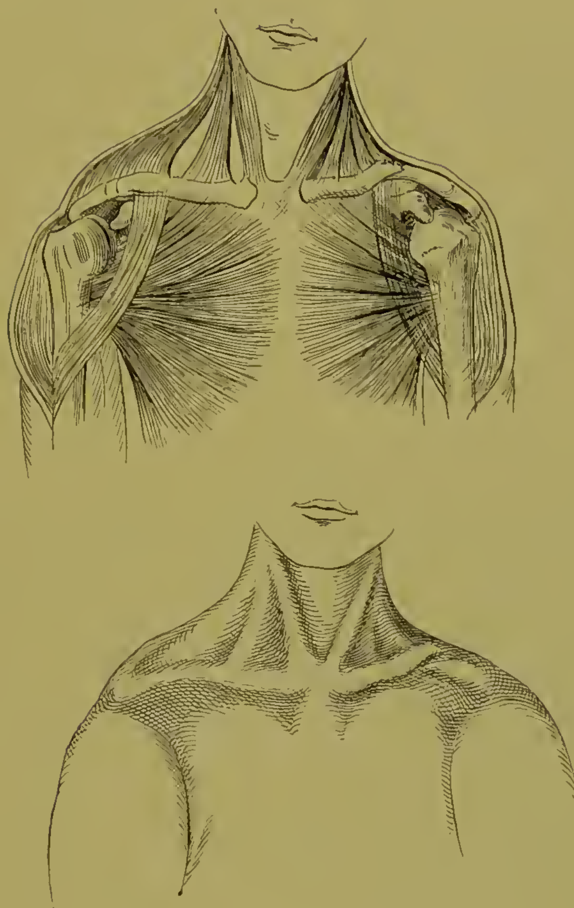

Fig. 14.—Fracture of the left clavicle.

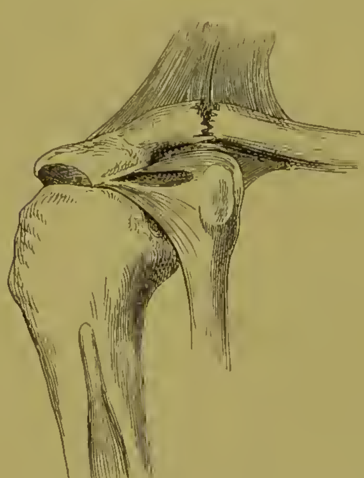

Fig. 15.—Fracture of the clavicle. Slight axial displacement (after Hoffa).

clavicle are typical. The sternal end of the clavicle is elevated by the action of the sterno-cleido-mastoid muscle, while the acromial portion is pulled down by the weight of the arm and scapula. Thus, either simply an angle (Figs. 15 and 16) is formed, or the sternal end is overlapped by the acromial, the displacement so elevating the fragment that the deformity becomes rather conspicuous even from simple inspection. The clavicle having ceased to be the buttress between shoulder and

Fig. 16.—Fracture of the clavicle. Union after four weeks (axial displacement not reduced).

thorax, the shoulder sinks downward and inward. The motions of the arm, especially elevation and abduction, naturally become painful, a symptom that finds its illustrative expression by the patient generally supporting his elbow with the hand of the uninjured extremity. Instinctively the patient turns his hand toward the affected side in order to relax the sterno-cleido-mastoid muscle.

Diagnosis.—A simple fracture of the clavicle is easily recognized. Inspection reveals displacement.

which is sometimes considerable. The writer has observed cases in which the two fragments were each directed upward, like two vertical posts, so that the tissues were forcibly pressed upward. Thus a picture, not unlike that of a tumor of the neck was created. (Fig. 17.) More or less dyspnea, which, of course, disappears as soon as reposition is effected, is also

Fig. 17.—Fracture of the clavicle, showing considerable displacement, the upper fragment riding and lifting the integument forcibly upward, in a man thirty years of age (one week after the injury).

present in these cases. If there is a clear history, fracture of the clavicle is seldom overlooked; but practical experience shows that it often happens that infants are dropped by careless nurses or mothers, and that the crying of the patients is attributed to some entirely different cause. To hide the carelessness, a misleading report is sometimes given. Cases of fracture of the infantile clavicle are not rare in

which nothing but an inability to lift the arm is noticed, and an ointment for the forearm is prescribed. Nothing shows the necessity of making it a principle always to denude the whole body in children, whenever there is the slightest suspicion of an injury

Fig. 18.—Deformity caused by considerable displacement in a boy of ten years.

to any bone, more especially since this oversight may lead to most unpleasant consequences to the attendant physician.

The swelling on the point of fracture, the near approach of the injured shoulder to the sternum, and the characteristic interruption in the bone line, common here as in all fractures, are all features that can easily be palpated, and are all unmistakable symptoms.

Displacement is naturally absent in simple infraction,

and sometimes also in real fracture. In these rare cases it is the local pain in the first place that claims attention. It is obvious that, the signs of displacement lacking, such conditions are often overlooked. A mistake of this kind fortunately does not amount to much practically, since such cases are almost sure to heal without any treatment. (Fig. 16.) Whenever doubt exists, the Röntgen rays will furnish elucidation.

Course.—Union is generally perfect in three weeks.

Fig. 19.—Deformity caused by considerable displacement in the case illustrated by figure 18. Skiagram taken six weeks after the injury.

Even in cases of extensive displacement, where reduction is entirely neglected, union is to be expected. It is astonishing, that even where the overlapping of the fragments causes considerable shortening of the clavicle, the function of the shoulder or the arm is but seldom impaired. (See Figs. 18 and 19.)

From a cosmetic point of view such outcome will certainly be condemned. The disfigurement caused by the protrusion of the skin on account of the over-

lapping fragment is sometimes great, and if it concerns a female patient, the deformity will be liable to cause no little unhappiness. (Figs. 20 and 21.) It is remarkable, however, that sometimes there is hardly any protrusion, in spite of the riding of the very much displaced fragments. If there be such callus prolifera-

Fig. 20.—Typical fracture of the clavicle in a girl of eight years. Marked deformity, caused by riding of upper fragment.

tion, pressure may be conveyed to the brachial plexus. Pseudarthrosis is extremely rare in fractures of the clavicle.

Treatment.—As in all other fractures, prompt reposition is the main indication. This is generally done without any difficulty. It is made best while an assistant stands behind the patient, who sits in a chair. The

attendant pulls the injured shoulder backward. If reposition is imperfect, more force may have to be applied by the assistant pressing his knee against the back of the patient while reposition is tried. Thus reposition is easy; but keeping the fragments well immobilized is a much more difficult matter. Many kinds of appliances have been devised for this purpose, most of them being intended to raise the shoulder and to bring it back and outward, so as to counteract the

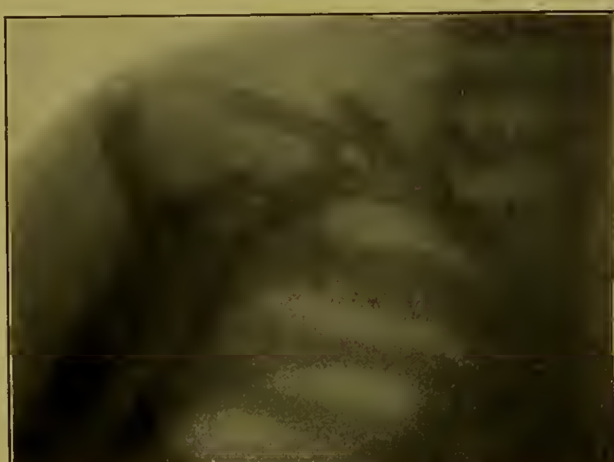

Fig. 21.—Fracture of the clavicle showing riding of the fragments. Same case as figure 20. Skiagram taken two days after the injury.

displacing causes. These demands are well fulfilled by *Velpeau's dressing*, which is applied best by means of a long roller bandage. After a small pad is put into the axilla of the injured side, the arm is conducted over the anterior thoracic wall and the hand is placed upon the uninjured shoulder. It is evident that this elevation of the hand pushes the injured shoulder as far upward as possible, while the adductor of the arm pulls the acromial end outward. The bandage is carried obliquely from the sound axilla over the injured

shoulder down to the elbow, whence it runs up to the axilla again, and so forth.

Sayre's dressing (Fig. 22) is also much in favor. It demands three long, wide, adhesive plaster strips, the first one of them being attached to the inner surface of the upper arm of the injured side and passing around the anterior surface of the arm backward over the back to the chest wall. (Fig. 22 *a*.) This procedure, which rotates the upper arm outward, prevents the clavicle from riding upward and pushes the elbow portion of

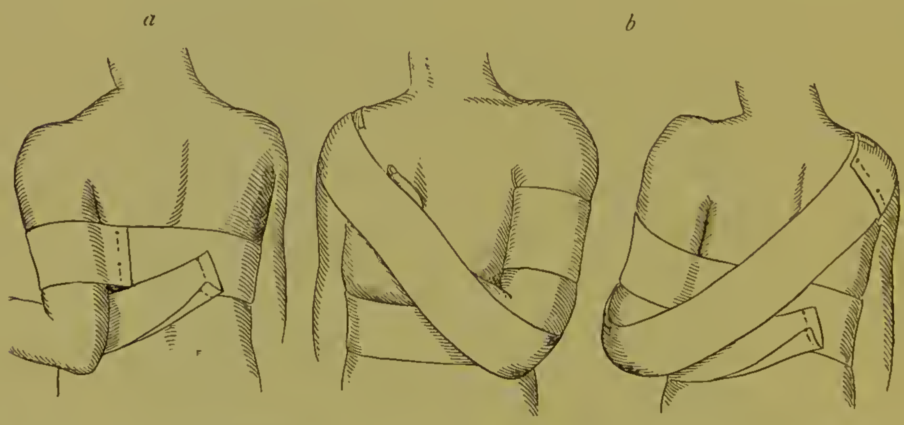

Fig. 22.—Sayre's dressing: *a*, First strip; *b*, second strip, front and back views.

the humerus (and thus the shoulder also) backward, upward, and outward by pressing the elbow forward, downward, and inward. The second strip fortifies the position of the first by fastening the arm and hand of the injured side to the chest wall. (Fig. 22 *b*.) The strip starts from the uninjured shoulder, and, passing over the antibrachium and elbow to the dorsum, returns to the starting-point on the shoulder again. Now the fragments must be accurately adjusted and the deformity will necessarily disappear. The third strip, therefore, serves as a kind of a mitella only. It

surrounds the carpus of the injured side, and runs to the back after having passed over the fractured area. It, however, elevates the hand somewhat and presses slightly upon the fragments.

The Sayre dressing, while most ingenious, does not afford so firm a support as the Velpeau bandage or the author's. Furthermore, it has the great disadvantage that the adhesive plaster often creates such a dermatitis that in summer time it can not be tolerated.

The results obtained by the author's dressing were just as good, without exposing the patients to any discomfort. Absolute firmness is warranted by employing a moss splint that immobilizes the shoulder as well as the elbow. (Fig. 23.)

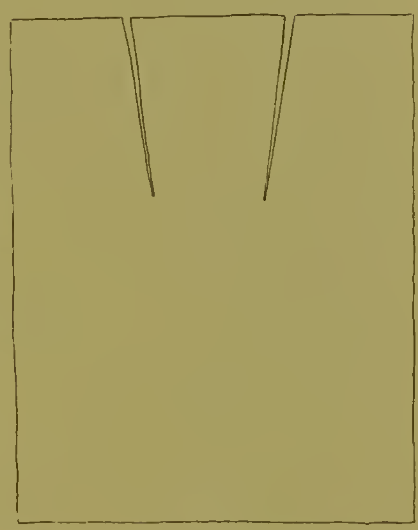

Fig. 23.—Moss splint, trimmed for author's dressing. (See Fig. 24 *b*.)

The first step consists in drawing the shoulders backward, while pressing the thorax (Fig. 24 *a*) or the knee against the patient's scapula. Then a moss splint, suitably trimmed for proper adaptation (Fig. 23), is applied to the shoulder. (Fig. 24 *b*.) The elbow portion is molded and folded in the same manner. If slightly dipped into lukewarm water, it will adapt itself well to the contour of the shoulder.

The axilla is filled out with a pad of borated gauze. The hand also rests on a thick layer of borated gauze at the anterior thoracic wall, the fingers reaching up to the sound clavicle.

a *b* *c*

Fig. 24.—*a*, Reposition of fracture of the clavicle by drawing the shoulders backward and pressing the surgeon's thorax against the patient's scapula. *b*, Molding the shoulder portion of the moss splint. *c*, Author's dressing for fracture of the clavicle (completed).

Now the sunken arm is elevated by passing a roller bandage under the elbow, over the clavicular area of the healthy side. Then the lower third of the humerus is tightly drawn to the thorax and transversely fixed by a turn of the bandage. Finally, the elbow is supported by another turn passing over the injured area. (Fig. 24 *c.*) In children this dressing should be protected by broad strips of rubber adhesive plaster.

The author's dressing can be used in all the different types of clavicular fracture, but has proved to be especially useful when simultaneous injuries of the integument exist. (Compare p. 66 on moss dressings.)

SCAPULA.

Fractures of the scapula are rare, comprising only about one per cent. of all fractures. They concern either its *spine*, *body* (Fig. 25), *neck* (Fig. 26), the *acromion* (also Fig. 25), or the *coracoid process*.

Fractures of the **spine and the body of the scapula** are either simple fissures or fractures without any displacement, and consequently heal under almost any treatment. The principal signs are ecchymosis, crepitus, and pain. A correct diagnosis is often only possible with the aid of the Röntgen rays.

The *treatment* consists in immobilizing the arm with a splint, which surrounds the shoulder and passes over the scapula to the spine.

Fracture of the **neck of the scapula** (Fig. 26) in itself is extremely rare. It occurs more frequently in connection with a fracture of the floor of the glenoid cavity. The severed glenoid cavity sinking downward and inward, the shoulder loses its convex shape and the arm appears longer, so that this injury

is very liable to be confounded with the subcoracoid dislocation of the humerus. (Figs. 34, 35, 36.) But in this fracture the arm is freely movable in all directions, while in dislocation free motion is arrested. Furthermore, the convexity of the shoulder at once springs up again as soon as the humerus is pushed upward and outward, while in the case of dislocation the nor-

Fig. 25.—Stellate splinter fracture of the scapula.

mal contour of the shoulder appears only when the reduction has been made perfect.

The *treatment* consists in Velpeau's or the author's dressing. (See p. 87.) Union is generally complete in four weeks.

Fracture of the **acromion** (compare Fig. 25) is nearly always caused by direct violence (fall or blow). The signs—generally well marked—are ecchymosis,

pain, crepitus, flattening, and sinking downward and inward. Even if there be extensive blood extravasation, the sharply localized pain and the crepitus,

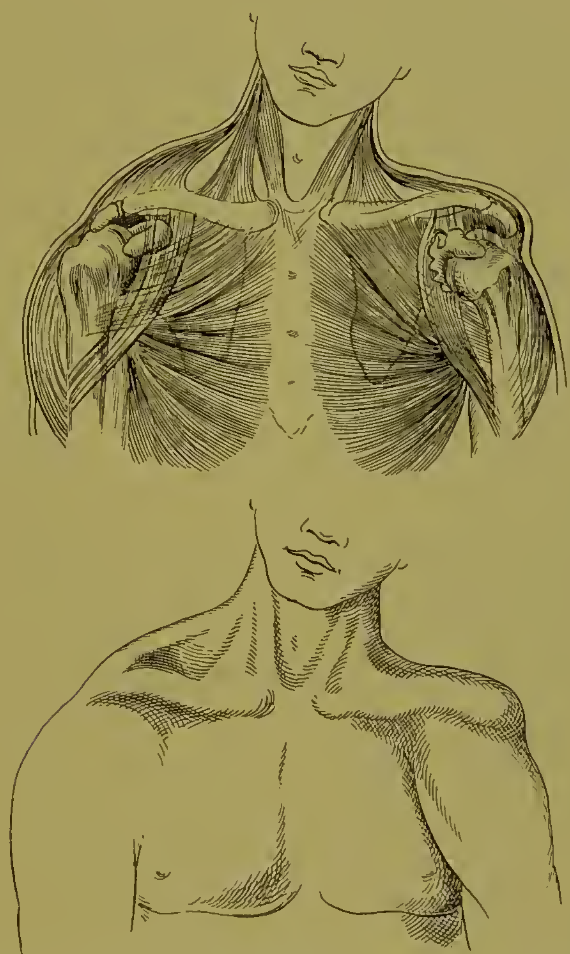

Fig. 26.—Fracture of the neck of the scapula (after Hoffa).

which is never absent, are symptoms too characteristic to permit of a mistake.

The *treatment* is practically the same as that of fracture of the neck of the scapula. (See p. 90.) Union is generally perfect in about three weeks. Even if

there be fibrous union only, there is no functional disturbance.

Fracture of the **coracoid process** is rare and is also generally caused by direct violence. After this fracture the short head of the biceps muscle and the coracobrachialis and the pectoralis minor muscles pull the coracoid process inward and downward. The displacement is hardly noticeable, but the localized pain, the mobility of the fragment, and the disturbance of the function of the arm are marked symptoms.

The *treatment* is the same as that of the fracture of the neck of the scapula.

HUMERUS.

Fractures of the humerus comprise about eight per cent. of all fractures. They are best classified according to their seat, as fractures of the *upper end*, of the *diaphysis*, and of the *lower end*. All the different varieties of fracture of the humerus also occur in children.

Fractures of the **upper end of the humerus** are caused either by direct or indirect violence. They are subdivided as fractures of the anatomic and surgical necks,—including the traumatic epiphyseal solution of the upper end of the humerus, the so-called transtubercular fracture,—and fractures of the tuberculum majus and minus.

I. Fracture of the anatomic neck of the humerus (Fig. 27) is caused by direct violence, especially by a fall upon the outstretched hand. Like the intracapsular fracture of the femur, it is an intra-articular fracture. It is especially observed in aged persons,

which fact is well explained by the senile atrophy of the bone tissue.

The *signs* are abnormal mobility, crepitus, loss of function, and pain. The extracapsular character naturally prevents palpation of the second fragment. If the tubercula, together with the diaphysis, are inwardly displaced, the shoulder becomes flattened so that a

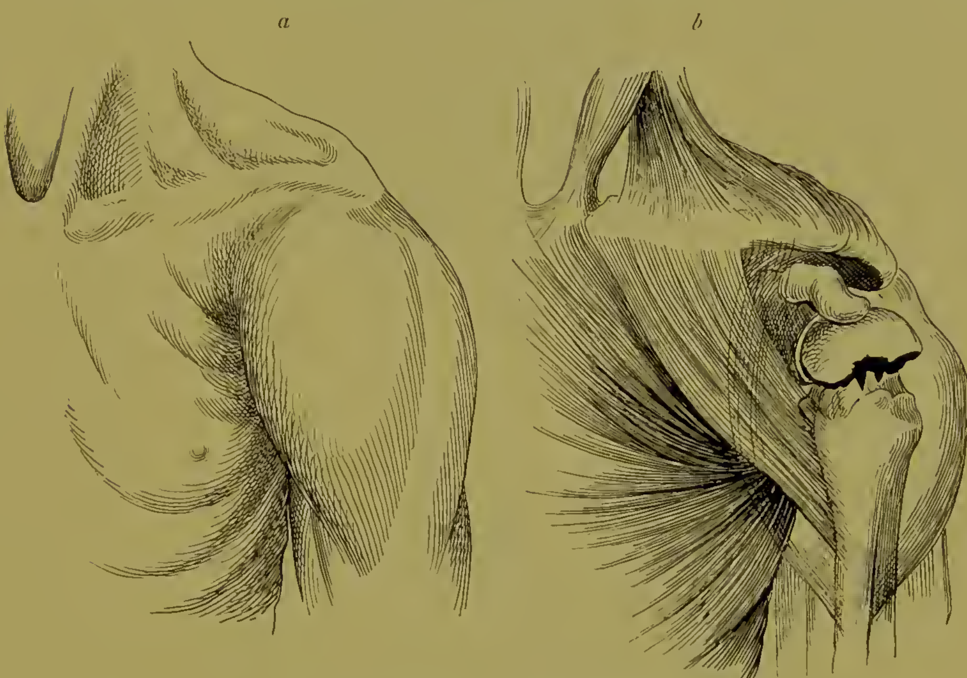

Fig. 27.—*a*, Exterior appearance; *b*, fractured head, showing slight outward displacement (after Hoffa).

deformity similar to that of the subcoracoid dislocation is created. (Compare Fig. 36.) But it should be remembered that in fracture of the anatomic neck there is much more shortening of the arm than in dislocation, and that in dislocation free motion is arrested. Even in the case of impaction, mobility is much freer in the case of a fracture than it is in a dislocation. So far as the possibility of confounding this type

with the fracture of the scapular neck (Fig. 26) is concerned, in which the arm is also pushed toward the chest, it should be considered that in fracture of the neck of the humerus (Fig. 33) the arm is shortened, while in fracture of the neck of the scapula it is elongated.

If impaction be present, union may become perfect; if not, the severed fragment may undergo necrosis, since it would receive no blood-supply. Fortunately, this fracture type is not absolutely intracapsular in most cases; that is to say, the fragment is not severed in its whole extent, but it still adheres by portions of the capsule, so that the vascular supply is not entirely cut off. Sometimes callus proliferation is so abundant that the function of the joint is inhibited. (Figs. 29 and 30.)

The *treatment* consists best in the application of a well-padded collar splint, which extends from the neck over the shoulder and the extensor portion of the arm and antibrachium to the dorsum of the hand. Extension by weight is also advised. But while this method of treatment is excellent as far as the final result is concerned, it has the disadvantage of confining the patient to bed.

II. Fracture of the surgical neck of the humerus occurs much more frequently than fracture of the anatomic neck, and is generally caused by direct violence (fall on the shoulder); sometimes indirectly (fall on the hand or elbow). It has its analogue in the extracapsular fracture of the neck of the femur. It is common in all ages. (Figs. 31, 33.)

Signs.—The line of fracture is found below the tuberosities. The arm is shortened more than in frac-

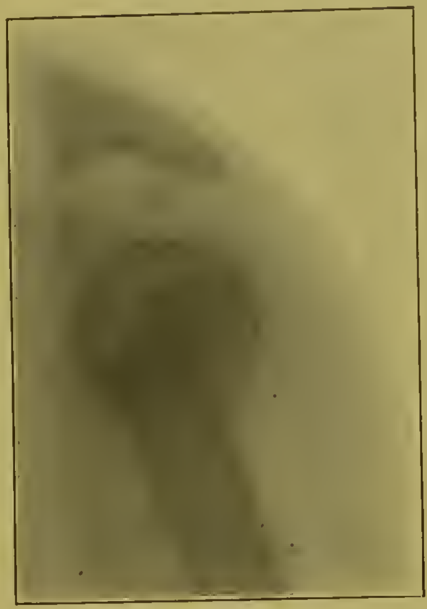

Fig. 28.—Fracture of the anatomic neck of the humerus, showing outward displacement of the head and impaction ; girl of nine years. (One week after the injury.)

Fig. 29.—Fracture of the anatomic neck of the humerus, showing outward displacement of head and abundant callus proliferation in a man of sixty-four years (three weeks after the injury).

Fig. 30.—Fracture of the anatomic neck of the humerus, showing abundant callus proliferation, inhibiting free motion.

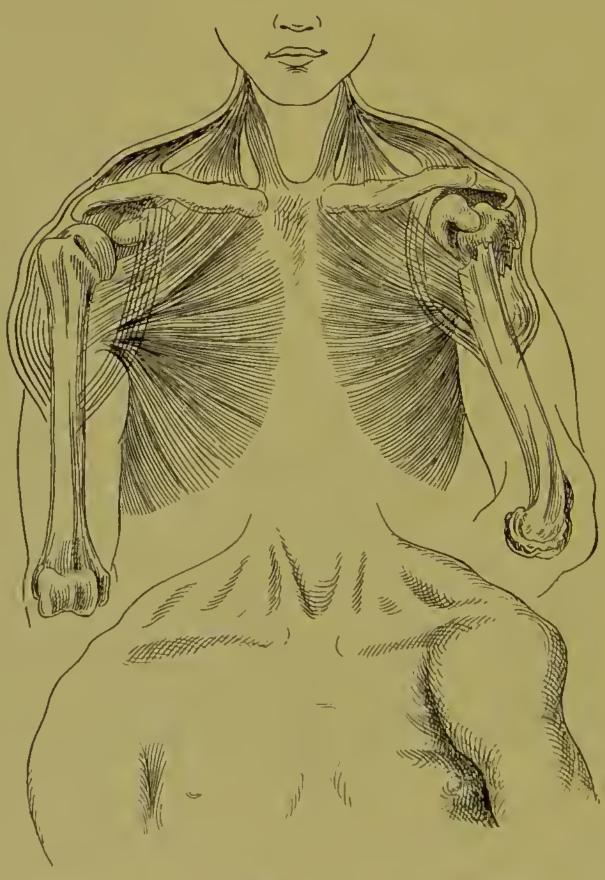

Fig. 31.—Fracture of the surgical neck of the humerus (after Hoffa).

Fig. 32.—Ideal union in fracture of the surgical neck of the humerus, showing perfect apposition and normal callus formation, in a boy of eight years. (Two weeks after the injury.)

Fig. 33.—Fracture of surgical neck of left humerus. Outer view, showing angular deformity below the fracture, and ecchymosis in front of the shoulder.

ture of the anatomic neck. The lower fragment is pushed inward, the pectoralis major and latissimus dorsi muscles pulling it toward the thorax; and at the same time it is drawn upward by the biceps, triceps, and coracobrachialis muscles. There is also ecchymosis, abnormal mobility, displacement, and generally crepitus. As to displacement, it is found that the end of the diaphysis may be directed inward, in other cases outward; the latter variety being by far the rarer one. In case of inward displacement (Fig. 33) the arm is abducted and the axis of the arm is directed toward the clavicle or the coracoid process, while in outward displacement the arm is kept in adduction. If the fracture is impacted, it may be confounded with dislocation. In preglenoid (subcoracoid) dislocation (Figs. 34 and 35) the infraclavicular fossa, on account of the projection of the dislocated head of the humerus, appears as if it were filled up. If the surgeon only takes the trouble of palpating this protruding point, he will receive the impression of the presence of a hard body of globular shape, *which follows all motions of the shaft of the humerus.* Now, there is no other organ in this region that could be confounded with this projection represented by the dislocated head of the humerus. Indeed, the flattening of the shoulder, the axial change, and the flat prominence of the anterior aspect of the axillary region should be sufficient indications of the presence of a dislocation. And if there be a subglenoid (axillary) dislocation (Fig. 36), there must invariably be a diastasis between the head of the humerus and the acromion, which is of such considerable extent, sometimes, that the fingers can be introduced into the gap. The

surgeon should, therefore, always try to insert his hand between the acromion and the head of the humerus, because if he succeeds, he is almost sure to have a dislocation to deal with, while if he does not, he knows that the head of the humerus is at its proper place. This would indicate that if there be

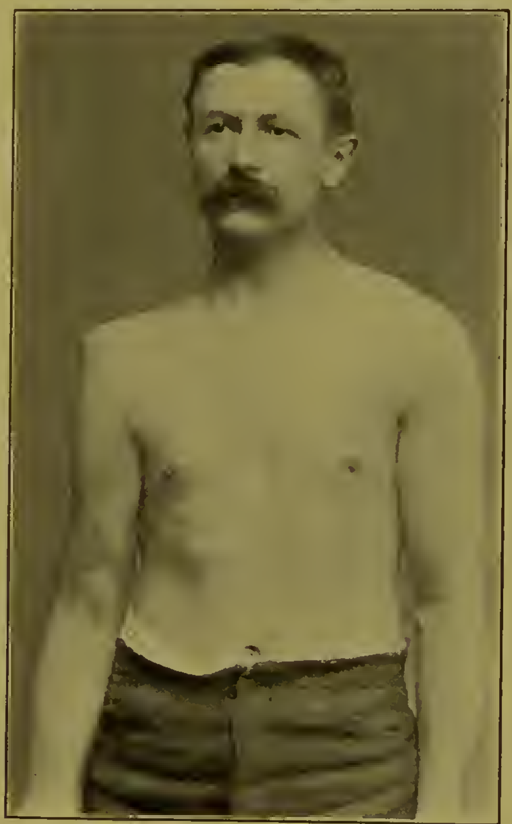

Fig. 34.—Preglenoid dislocation of the right humerus (front view).

false motion, a fracture must be assumed. If the arm is now rotated, while the head is steadied, *the latter will not move.* Sometimes the rough edges of the fragments can be palpated, if the axillary portion is firmly grasped. As to further contradistinction from dislocation and from fracture of the anatomic

neck, compare page 93. In tumors of the shoulder (Fig. 37), in inflammatory (rheumatic) and tubercular processes, it happens sometimes that if a history of an injury is given, the swelling is erroneously taken for callus proliferation.

Treatment.—Reposition is accomplished by pulling

Fig. 35.—Preglenoid dislocation of the right humerus (back view).

the arm downward and outward, under anesthesia, if necessary. Immobilization is attained either by a collar splint (see p. 45) or by the application of a plaster-of-Paris dressing, which is supported by coaptation splints around the fractured area and its immediate vicinity. An axillary pad should be employed

and the forearm should be kept rectangularly bandaged. If there be great tendency to displacement, as is especially found in oblique fractures of the surgical neck of the humerus, permanent extension, while the patient is confined to bed, should be preferred. In a week the patient can get up, after which extension is

Fig. 36.—Subglenoid dislocation.

employed during the night only, the patient being permitted by day to walk around after a collar splint has been applied. (Fig. 8.) As shown by the skiagram (Fig. 32), excellent results can be obtained by this treatment.

In this connection the **traumatic epiphyseal separation**

of the upper end of the humerus must also be mentioned, a condition frequently observed in children before the process of ossification in the epiphyseal cartilage is complete.

The *signs* are about the same as those of fracture of the surgical neck of the humerus, except that the

Fig. 37.—Osteosarcoma developing after a fall upon the outstretched hand, and erroneously taken for callus proliferation. (See p. 100.)

crepitus is less marked on account of the soft character of the friction between the fractured surfaces (cartilaginous crepitus).

The *treatment* is the same as in fracture of the surgical neck. It is sometimes impossible to keep the fragments in good position, or even to reduce them at all. When reposition is impossible, the fragments

must be united by nailing or sewing them together. (See p. 69.) If reposition fails to be perfect in children, further growth of the bone is arrested.

III. Transtubercular fracture (Fig. 38) is always the result of direct violence. The line of fracture is on a

Fig. 38.—Transtubercular fracture caused by direct violence, in a man of forty-five years (eight weeks after the injury), leaving considerable functional disturbance.

level with the tubercula, and its direction is transverse. There is a marked depression below the acromion. Crepitus can always be produced by rotating the arm, provided there is no impaction. Displacement

is nearly always present. The nature of this injury generally not being recognized without the aid of the Röntgen rays, it is obvious that no effort is made to reduce the displaced portion. Consequently, there is

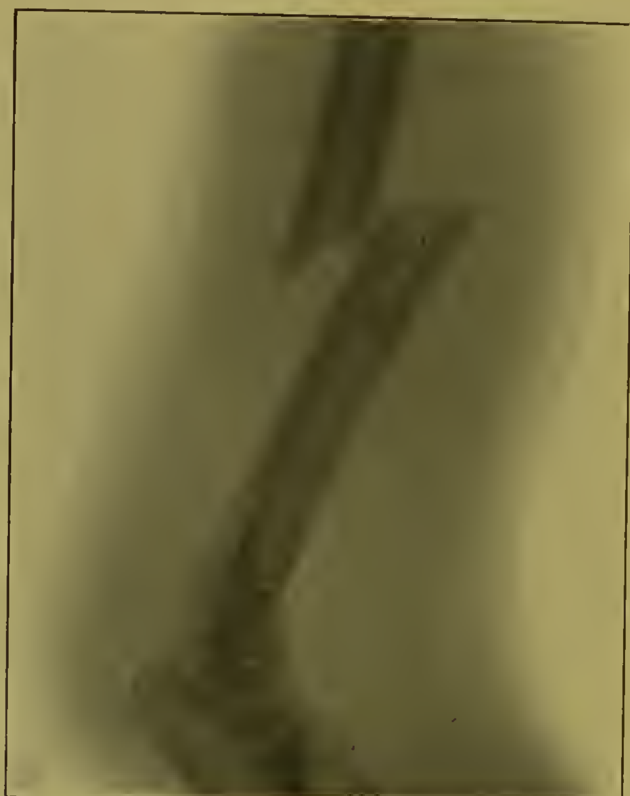

Fig. 39.—Fracture of the diaphysis of the humerus, showing riding of fragments, in a lad of fifteen years. (One day after the injury.)

always more or less deformity and interference with free motion in the joint.

The *treatment* consists in proper reposition under the control of the Röntgen rays, and the after-treatment is identical with that for fracture of the neck of the humerus.

IV. Fracture of the tuberculum majus or minus is always accompanied by a dislocation, and is character-

ized by pain, functional disturbance, and diastasis of the fractured area.

The *treatment* consists of relaxation of the muscles that are inserted at the tubercula by proper rotation, and of immobilization by a collar splint.

Fracture of the diaphysis of the humerus is in the great majority of cases caused by direct violence, and is of frequent occurrence. While in children (Fig. 39) the transverse direction is predominant, in adults the line of fracture is generally oblique. (Fig. 40.) As a rule, there is but little displacement in transverse fractures of the shaft, while in oblique fractures displacement is always present. It is then either longitudinal or axial.

The *signs* are ecchymosis, pain, crepitus, abnormal mobility, and loss of function, besides displacement. In most cases union becomes perfect in from five to six weeks.

The radial nerve may experience the same fate, since its situation directly on the periosteum favors its laceration in splintering fractures. The same nerve may also be injured by overabundant callus proliferation, so that it becomes tightly embedded—in fact, incarcerated—in the callus-tissue. (See Fig. 41.) The consequences of this condition are grave disturbances in the sensory as well as in the motor sphere. Protrusion of badly united fragments, conveying pressure upon the brachial artery or vein, produces extensive edema of the extremity. (Fig. 40.)

Treatment.—If there is pronounced tendency to displacement, a collar splint (p. 45) will correct the trouble. Any other kind of splint that has a shoulder-cap would be useful, if properly applied. In applying

any kind of dressings great care should be taken to avoid pressure on the axilla. If there be marked

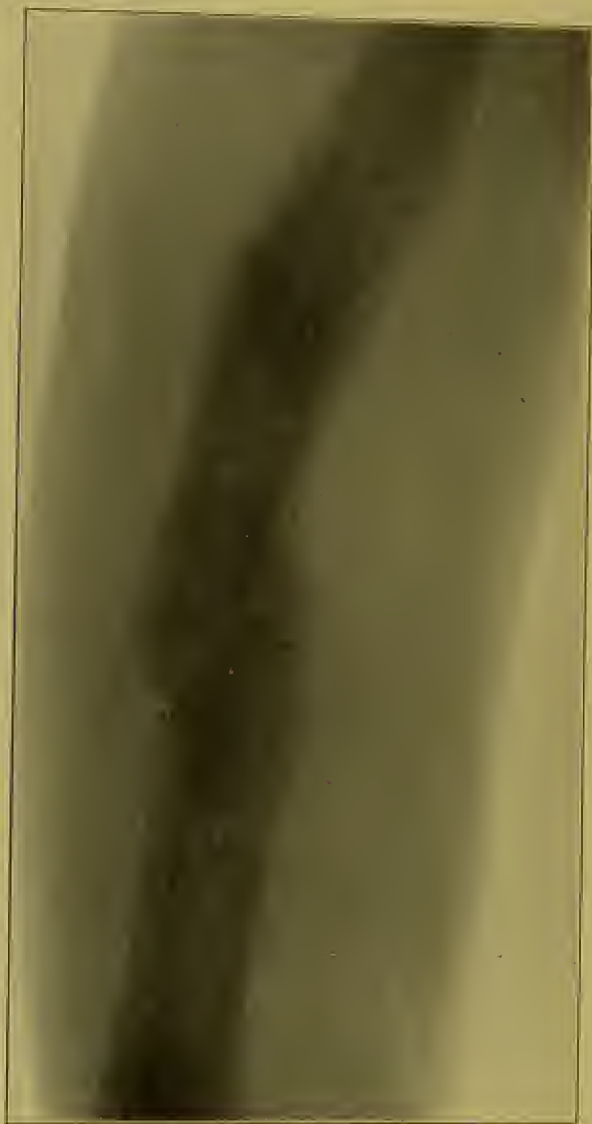

Fig. 40.—Double fracture of the diaphysis of the humerus, in a man of fifty years (was rickety when a child), two months after the injury. Protruding lower fragment, causing extensive edema of arm and hand by pressure upon the brachial vessels.

tendency to displacement, extension by a heavy weight, attached to an adhesive plaster dressing, should be made for at least two weeks.

In a case of pressure-paralysis of the radial nerve, caused by callus proliferation, neurolysis, as described on page 71, should be performed. In most of the cases where the incarceration of the nerve is relieved by chiseling off the callus-tissue the paralysis disappears promptly.

Pseudarthrosis is much more frequently observed in fracture of the humerus than in that of any other bone, the diaphysis preeminently being concerned. According to Gurlt, thirty-four per cent. of pseudarthroses affect the humerus. This deplorable condition is always due to the insufficient coaptation of the fragments, which generally permits the intervention of muscular tissue. Sometimes true new joints, containing cartilage and synovia, are formed, as described in pseudarthrosis of the tibia.

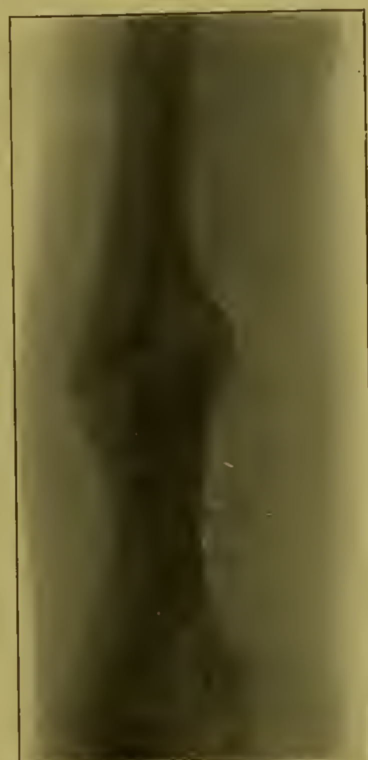

Fig. 41.—Abundant callus formation, induced by lateral displacement in fracture of the lower end of the humerus, and causing pressure on radial nerve.

In cases of short standing stretching the elbow and the application of a long extension splint, reaching from the hand to the shoulder, may be employed. Then, while the arm hangs down, permanent stretching of the fractured area is accomplished. In most cases, however, subperiosteal resection followed by bone-suture must be performed.

Under the ægis of the Röntgen rays pseudarthrosis

of the humerus has become unpardonable, since under their guidance any slipping-out of the fragments can easily be noticed and corrected.

Fractures of the lower end of the humerus are frequent and show different varieties, the correct recognition of which is often extremely difficult, and without the aid of the Röntgen rays is sometimes impossible. They are usually caused by direct violence. In children they are nearly invariably the result of falls. Separation of the lower epiphysis in childhood is sometimes confounded with backward dislocation of the radius and ulna. The different varieties are best classified as *supra-condylar*, *diacondylar* (including epiphyseal separation), *epicondylar*, and *inter-condylar* (including intra-articular separation of the capitulum humeri).

Fig. 42.—Exterior view of supracondylar fracture.

I. Supracondylar fracture (Figs. 42 and 43) is transverse in the majority of cases, but sometimes its line is oblique. It principally occurs in children under twelve years of age—a period in which the locality of this fracture type is determined by the softness of the bone-tissue. This explains why in children a fracture nearly always results from a fall upon the hand or elbow, while the same accident generally produces a dislocation in adults. In children this type is sometimes complicated by a vertical frac

ture, which extends into the joint, so that the so-called T-fracture results. Supracondylar fracture has been erroneously described by some authors as epiphyseal separation.

The *signs* of this fracture often resemble those of the backward dislocation of the antibrachium (see Figs. 44 and 45), there being three main signs com-

Fig. 43.—Oblique supracondylar fracture in a man of thirty-five years (four days after the injury).

mon to both injuries: namely, shortening, false position, and the axial direction. There is always a backward displacement, the lower fragment being pulled back by the triceps muscle. (Fig. 42, 43.) But in contrast to dislocation, abnormal mobility and crepitus are always present in fracture. It must also be considered that flexion at a right angle as well as extension to the full limit is always possible in fracture.

Another striking point of differentiation is the return of the deformity, whenever reposition has been made; while in dislocation the deformity disappears as soon as reposition is done. A further pathognomonic sign is the absence of the projection of the radial head, which in a case of dislocation can always be easily palpated. The olecranon is always situated higher in dislocation than in fracture. In cases in which it

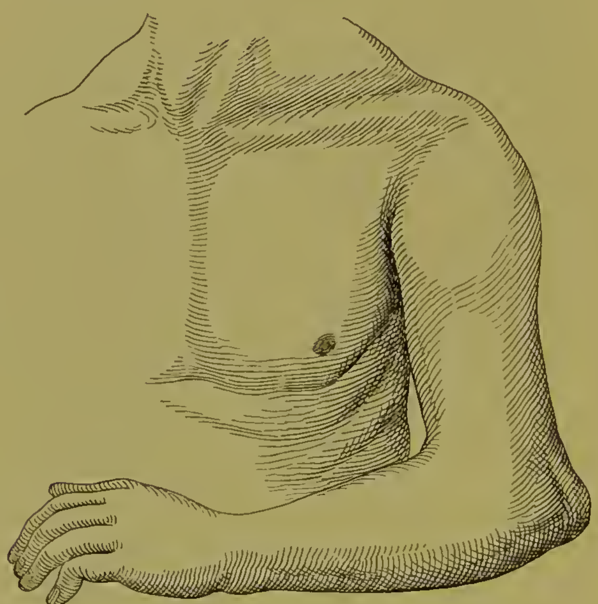

Fig. 44.—Backward dislocation of the elbow (exterior view).

is pushed backward together with the transverse epiphyseal line, it is found in the direction of that line.

To give a résumé, it should be considered that in dislocation the flexor side of the forearm and the extensor side of the upper arm appear shortened, the tendon of the triceps muscle appearing like a small arch, the concavity of which is directed toward the olecranon. This bone portion makes itself conspicuous then as a marked projection posteriorly. Thus, two

lateral grooves are formed. It will also be found that the trochlea can be palpated in front, while the outlines of the joint-surface of the radial head can be easily grasped in the back. In dislocation the transverse diameter of the joint always remains normal.

The *diagnosis* of fracture is indisputable, as soon as the presence of false motion is established. This is done by grasping the lower fragment on its projec-

Fig. 45.—Backward dislocation of the elbow.

tions, the epicondyles, and pushing them to and fro. Crepitus is also never absent during these manipulations. In T-fractures the prognosis is particularly grave in view of the severe complications of the joint.

The *treatment* consists in reducing the fragment by making extension on the hand and antibrachium under anesthesia, if necessary. Whether immobilization is

better kept up in the extended or in the flexed position should be determined by the ease with which the fragments can be kept reduced in either of them. In most cases the decision of this much-discussed question should be left to the surgical instinct. There is no doubt that the rectangular position of the arm is by far the most agreeable for the patient; but it should not be the consideration of the patient's comfort that decides the position in so important an in-

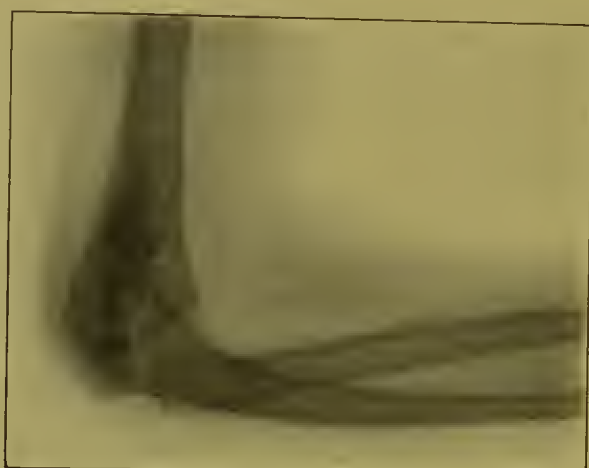

Fig. 46.—Supracondylar fracture, showing slight backward displacement, in a girl of ten years. (Two months after the injury.)

jury, but that plan should be adopted that assures the securest and most perfect apposition.

A circular plaster-of-Paris dressing, reaching from the shoulder to the wrist, is preferred by the author for immobilization. In most cases the fragment is best reduced and retained while forcible traction is made on the hand by an assistant, the surgeon or another assistant pushing the fragment inward with the left thumb. During this manipulation the bandages are applied. If after a week's time the rectangular

position is gently and gradually resumed, the tendency to displacement having been overcome, the question of comfort may be considered.

More than in any other fracture type, frequent inspection, control by the Röntgen rays, and eventual change of dressing is indicated. After three weeks, active and passive motion, together with massage treatment, should begin. It is only when thorough control is practised throughout the treatment that the untoward outcome of varus or valgus formation is certainly prevented.

Fig. 47.—Diacondylar fracture, causing considerable forward displacement, in a boy of twelve years (outer view).

If the tendency to displacement can not be overcome, extension, in combination with a wire splint, should be used for two weeks.

The radial as well as the median nerve may become lacerated by the splintering of the bone. Whenever these injuries are diagnosticated, which is always possible under the auspices of the rays (compare Fig. 41), neurorrhaphy should be performed without delay. The cubital vessels may become lacerated in the same manner, in which case immediate ligation alone can prevent gangrene of the arm.

II. **Diacondylar fracture** (fracture of the cubital pro-

cess) (Figs. 47 and 48) is caused directly by a fall upon the elbow or indirectly by a fall upon the hand, and is rather rare. It always extends into the joint, and is, therefore, in fact, an intra-articular fracture. The line of fracture is transverse, as a rule, and runs alongside the cartilaginous joint-surface.

The *treatment* must be conducted after the same principles as that of the supracondylar fracture, with

Fig. 48.—Diacondylar fracture showing displaced fragment attached in oblique direction, thus causing a resemblance to backward dislocation of the forearm. Skiagram of figure 47, taken six weeks after the injury.

the difference that motion and massage must begin as early as one week after the injury is sustained.

Epiphyseal separation in children must be considered under the same view, and the treatment should be conducted after the same principles as the diacondylar fracture. They are of either the osseous (Fig. 49) or the cartilaginous (Fig. 50) type.

III. Epicondylar fracture is far more frequent than the former varieties. It is caused mainly by direct violence, and especially by a fall upon one or the other side of the elbow region. It is either *oblique* and extends into the joint (*intra-articular epicondylar fracture*), or *extra-articular* and concerns the epicondyle only (*isolated epicondylar fracture*).

The *intra-articular epicondylar* fracture, or the epicondylar fracture proper, concerns either the internal or the external epicondyle, and its line is always

Fig. 49.—Osteo-epiphyseal separation of lower end of the humerus in a boy of five years, showing no displacement (one day after the injury).

oblique. The internal epicondyle becomes fractured if the fall is sustained while the arm is abducted; but the external epicondyle is fractured while the arm is in adduction. In both instances the line of fracture reaches the joint.

The *fracture of the internal epicondyle* (Fig. 51), which is caused by a fall upon the middle of the elbow, is rarer than the fracture of the external epicondyle.

The *signs* are slight displacement, crepitus, abnormal mobility, and swelling above the internal epicon-

dylar region, the latter so marked that this area becomes broader and more prominent than is natural. The internal epicondyle is more pointed, and therefore responds more readily to palpation, than the short and blunt external epicondyle.

The *treatment* consists in reducing the fragment by pulling and by retaining it properly by a pad, while the forearm is in flexion; and then securing with splints or a plaster-of-Paris dressing in a rectangular position.

Fig. 50.—Chondro-epiphyseal separation of lower end of humerus in a girl of two years, showing considerable displacement of fragment (two days after the injury).

The fracture of the *external epicondyle* is caused by direct violence as well as indirectly by a fall upon the hand. It is far more frequent than the fracture of the internal epicondyle.

The *signs* consist in the presence of an extravasation, abnormal adduction of the extended forearm, disturbance of function, pain above the epicondyle, crepitus, and the possibility of dislodging the fragment. The latter is frequently pulled upward by the biceps and the antibrachial muscles, which fact renders its

proper retention in place extremely difficult. It follows too frequently that the fragment becomes attached in a dislodged position, and thus it sometimes becomes an obstacle to the normal motion of the joint.

The *treatment* of the fractured external epicondyle is practically the same as that of its internal fellow. The reduction being more difficult, anesthesia is more frequently indicated to accomplish this purpose thoroughly. The dressing must be changed every few days. After the elapse of two weeks motion and

Fig. 51.—Intra-articular fracture of the internal epicondyle in a girl of thirteen years; slight displacement backward (two days after the injury).

massage treatment should be instituted. If, after two weeks, mobility of the elbow still appears to be arrested, it is advisable to use wire splints, which are bent to the shape of the elbow. They must be changed every day, in order to permit of slight motion. This is done by bending the elbow each day a little more, and accordingly bending the wire splint to the altered shape of the elbow. If the fragment can not be thus retained in proper position, extension by weight in the longitudinal direction of the humerus is to be tried.

Isolated epicondylar fracture—that is, extra-articular fracture of either the internal or external epicondyle (Figs. 52 and 53)—is caused by direct violence (a fall or blow) or, more frequently, by indirect violence (forcible abduction of the arm).

The most important sign is the displacement and the mobility of the fragment. There is also circumscribed extravasation. Pain is absent so long as the

Fig. 52.—Extra-articular fracture of left internal epicondyle, showing considerable protrusion of the epicondylar fragment and irregular callus formation, which inhibits stretching of the forearm, in a man of thirty-two years (ten weeks after the injury).

arm is but moderately moved, but becomes intense when extension and flexion are carried to their limits.

The *treatment* is practically the same as that of the intra-articular type. The extra-articular epicondylar type is sometimes found in connection with outward and inward dislocation.

IV. Intercondylar fracture (Fig. 54) is of a severe character. It is either longitudinal or oblique. In the

latter event it may be either T- or Y-shaped. The principal *sign* consists in the possibility of moving the fragments to and fro while palpation is employed. These types are often combined with severe injuries of the soft tissues. The *treatment* is the same as that of the supracondylar variety. (See p. 108.) In rare cases of non-union the fragment must be exposed and fastened to the surface from which it was detached.

In addition, *intra-articular separation* of the *capitulum humeri* (eminentia capitata humeri), which is caused

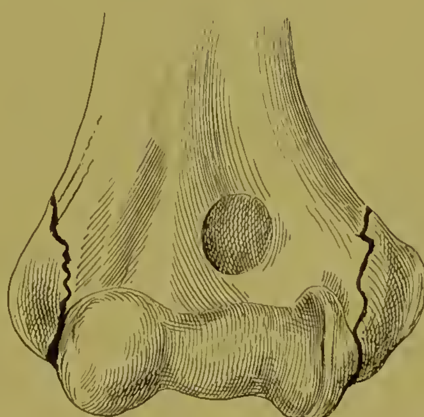

Fig. 53.—Extra-articular epicondylar fractures (after Hoffa).

by a fall upon the hand, remains yet to be mentioned. In this injury a small bone-fragment, after being totally severed, is retained as a free body in the joint. It is especially observed in young individuals.

The *signs* of this rare variety are slight abduction in the joint and the presence of an intra-articular exudation. Extension and supination are extremely painful. The severed fragment can generally be palpated between the external epicondyle and the capitulum radii. This injury may be confounded with the fracture of the latter. The diagnosis should always be verified by the

Röntgen rays. The treatment consists in the excision of the severed fragment.

Irregular callus (Fig. 52) is frequently produced in the different varieties of fracture of the lower end of the humerus, and naturally causes considerable functional disturbance in the elbow-joint. In most cases it is due to false coaptation of small bone-fragments. When

Fig. 54.—Longitudinal intercondylar fracture in a boy of sixteen years; impossibility of extension (three weeks after the injury).

several bone-fragments are severed, as in comminuted fractures, blameless *restitutio ad integrum* can be expected only from one who is absolutely ignorant of the anatomic relations of the elbow. Many surgeons have suffered innocently for results that, under the grave circumstances, were in reality praiseworthy. But unjust patients hold different views sometimes. What a blessing are the Röntgen rays, especially in

the treatment of this injury, which even under the guidance of the new light offers the greatest difficulties for proper apposition of the fragments! Of course, in such severe cases anesthesia should always be administered during reposition.

If, after thorough consolidation, the function of the elbow is prevented—as, for instance, by the protrusion or intervention of a badly united bone-fragment (Figs. 48, 54), or by the interposition of the olecranon between the fragments—removal of the cause by osteotomy is indicated. The arm is afterward best kept in an extension dressing.

In *oblique supracondylar fractures* oblique coaptation often takes place, so that after consolidation the axis of the elbow-joint also becomes oblique accordingly. If extended, the elbow shows an angle in either the interior or the inner direction, as the case may be —*cubitus valgus* or *varus*. In such cases a perfect cure can be obtained only by severing the badly united area with chisel and hammer.

FOREARM.

Fracture of the forearm, the extremity used so extensively for working, as well as for protecting the body (this member being instinctively outstretched when one is afraid of falling), is naturally very frequent.

It is divided into fracture of the:

1. *Ulna* (olecranon, coronoid process, diaphysis, styloid process, and fissure above the capitulum ulnæ).

2. *Radius* (capitulum and collum and the typical fracture of the lower end of the radius).

3. *Radius and ulna together*.

Differentiation from dislocation of the antibrachium

is of great importance. Regarding the fact that there are no less than twelve different types of dislocation of the elbow, the difficulty of contradistinction will be appreciated.

The ulna as well as the radius can be dislocated simultaneously toward four different directions: viz., outward and inward as well as forward and backward, the latter type being by far the most frequent. Or the ulna is dislocated backward while the radius is dislo-

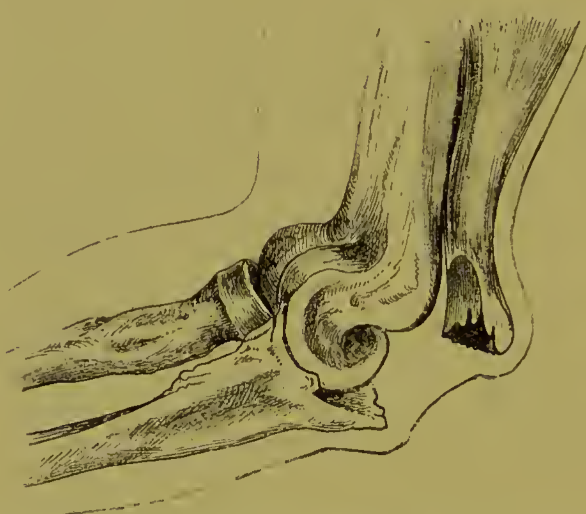

Fig. 55.—Fracture of the olecranon. Diastasis caused by the triceps muscle pulling the upper fragment upward (after Hoffa).

cated forward at the same time. The ulna may also be dislocated backward, while the radius may be dislocated either forward, or backward, or outward.

1. Ulna.—1. **Fracture of the olecranon** is nearly always caused by direct violence (fall on a stone or the margin of a staircase, or the like). (Figs. 55 and 56.) It is an exceptional occurrence when simple contraction of the triceps muscle produces it. According to surgical text-books, fracture of the olecranon is regarded as rare,

and it is judged to be less than 1 per cent. But the author's experience, supported by the Röntgen rays, has convinced him of the fallacy of this view, which is sanctified by its ancientness only. In the author's own experience, four cases of fracture of the olecranon process were discovered by skiagraphy among the material of his surgical clinics during a period of six months only. These cases represented a percentage of 8 among all the fractures observed

Fig. 56.—Fracture of the olecranon. Moderate degree of diastasis in a boy of fourteen years (four days after the injury).

there in that time. Admitting that this percentage was in part accidental, this fresh experience certainly points to a percentage higher than that usually assumed.

In two of the cases the author was not sure that he had to deal with a fracture of the olecranon until he had been informed by the aid of the Röntgen rays. It must naturally be seen that in the pre-Röntgenian era surgeons would have failed to register such cases

among the fractures of the olecranon. The author's experience furthermore contradicts the widely spread opinion that the fracture of the olecranon does not happen before the fifteenth year. It is observed from the tenth year, when the nucleus for ossification appears.

The fracture is almost always caused by direct violence upon the posterior portion of the elbow. In two cases there was but little diastasis, while in two others it was considerable. The line of fracture in each of these cases was transverse, three of the fractures being of the simple type and only one being comminuted.

Signs.—If the point of the insertion of the extensor muscles of the forearm is severed entirely, active extension is rendered impossible. The triceps muscle pulling the upper fragment upward, more or less diastasis is produced. (Fig. 55.) Crepitus is seldom absent. There is a circumscribed extravasation,—as a rule, of a globular shape,—which so covers the line of fracture that its presence may not always be readily discovered. In such instances it is only by deep palpation that the line is to be detected.

If the fragments are still kept in contact by the periosteum little or no diastasis may exist. Consequently, there will be no crepitus. It is especially in this fortunate event that the fracture is liable to be overlooked. It is evident that such cases give an excellent prognosis under any treatment. But if there is diastasis, bony union may remain an exception. Still, even in these examples, if the fragments remain near together bony union once in a while takes place. Usually, however, fibrous union is all that can be expected; but this is generally so firm that in the majority of cases the function of the elbow remains but little impaired.

The *treatment* consists in the application of a plaster-of-Paris splint in the hyperextended position while the displaced fragment is tightly grasped and pushed downward by the fingers of an assistant. The turns of the bandage are conducted around the pressing fingers in such a manner that at last a wall is formed around the digital impressions, which, after having become dry, so holds the reduced fragment in place that return of the piece is rendered impossible. (Compare Treatment of Fracture of the Patella.)

In simple cases the extension dressing can be changed into the rectangular after the lapse of about two weeks. After four weeks motion and massage must be employed. In the event of considerable extravasation, aspiratory puncture under thorough aseptic precautions is advisable before reduction is attempted. If all these points are carefully observed, suturing the fragments needs to be resorted to only in case of extreme diastasis and in compound fractures of the olecranon. The technic of wiring the fragments is essentially the same as in fracture of the patella.

Separation of the epiphysis of the olecranon is rare, and is to be viewed from the same standpoint as the fracture. It should be remembered that the epiphysis joins the diaphysis in the seventeenth year.

II. Fracture of the coronoid process of the ulna is mostly caused by indirect violence (fall on the outstretched hand and forearm). It represents a rare type. (Fig. 57.)

The *signs* are depression at the olecranon, so marked that the ulna appears to be dislocated backward. But the position of the radius, which remained unchanged, always differentiates the fracture from the dislocation. (Compare Fig. 45.) Further signs are the

intense pain felt when the process is touched, the crepitus, and the impossibility of extending the fore-arm to its limit. Palpation of the fragment is generally prevented by the thickness of the muscles that run over the fractured area.

This fracture type is sometimes combined with backward dislocation of both bones of the forearm.

The *treatment* consists in reposition of the fragment, which is done by forcible pulling on the forearm. The arm then is flexed at an acute angle and immo-

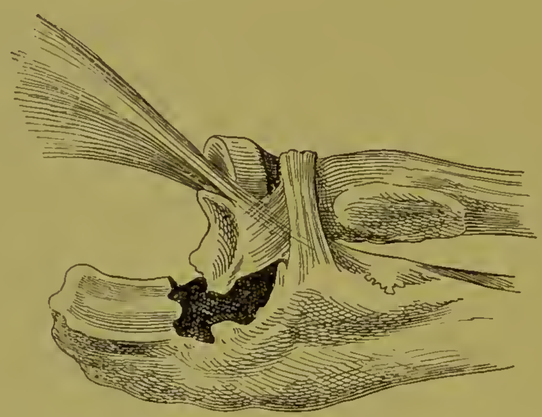

Fig. 57.—Fracture of the coronoid process of the ulna (after Hoffa).

bilized in this position by splints. When the swelling has subsided, a plaster-of-Paris dressing should be applied. After the lapse of two weeks the position is gradually changed until extension can be made. Passive motion and massage must be resorted to after three weeks.

In most cases, on account of the diastasis of the fragments, a fibrous union is all that can be looked for. Still, the function of the elbow is usually but little impaired even in this event. When there is an abundant callus proliferation, the function of the joint is

apt to suffer. In such cases the projecting bone-mass must be chiseled off.

III. Fracture of the diaphysis of the ulna (Figs. 58 and 59) is nearly always caused by direct violence (a fall or a blow warded off with the elevated antibrachium). The seat of the fracture is generally below the middle of the bone, where its diameter is smallest and the bone has the least muscular protection.

The *signs* are generally well marked, since the ulna appears to be folded inward at the point of fracture. There is ecchymosis, local pain, abnormal mobility, and crepitus. Usually, there is also an extravasation

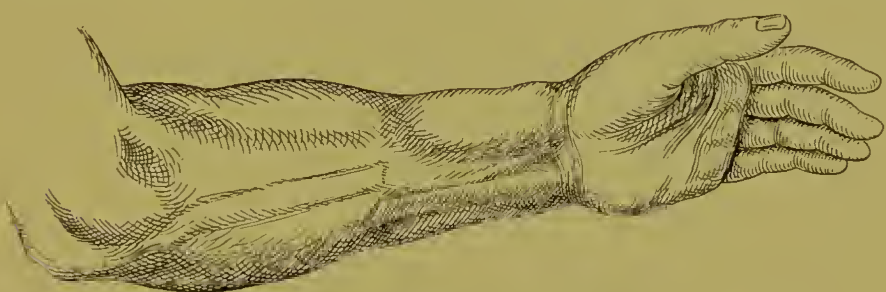

Fig. 58.—Exterior view of fracture of the diaphysis of the ulna.

surrounding the seat of fracture. Sometimes the signs are insignificant, as in the case illustrated by figure 60.

The *treatment* consists in the adaptation of two splints, reaching from the wrist to the elbow, after reposition has been accomplished by a strong pull. After adjustment and dressing, the position of the arm may be rectangular, and the forearm should be carried between pronation and supination.

In cases of soft callus (Fig. 61), sometimes occurring in childhood, immobilization must be kept up for months. Sometimes the shaft fractures at the upper third, in

which case it was taken for granted that this injury was always combined with a dislocation of the capitulum radii. But, as the Röntgen rays show in figure 62, such fractures happen without injuring the radius. As will be seen later, in our account of the lower end of the radius, as well as in that of malleolar fracture, disloca-

Fig. 59.—Fracture of ulnar diaphysis, showing slight displacement, in a man fifty years of age (four days after the injury). In spite of the inward displacement, and consequently the slight anterior bending of the radius, the symptoms were insignificant. The man (truckman) always attended to his heavy work. The moderate pain was attributed to contusion, and therefore no immobilization had been attempted.

tion or fracture of either bone of the forearm generally follows the reception of any amount of violence strong enough to displace the fragments of its broken fellow. Therefore it was *a priori* assumed that whenever considerable displacement in ulnar fractures is found, either fracture or dislocation of the radius will be present at the same time.

The treatment of fracture of the ulna at its upper third is essentially the same as that for fracture of any other portion of the ulnar diaphysis. Particular care, however, should be taken in this variety to exert slight pressure upon the capitulum radii by applying an adhesive plaster pad.

If the displaced fragment is pressed against the

Fig. 60.—Well united fracture of diaphysis of the ulna in a woman thirty-six years of age (ten days after the injury).

radius, consolidation may take place. (Fig. 63.) In this event supination becomes impossible. At an early stage reposition under anesthesia may be successfully tried, but later on osteotomy has to be resorted to.

IV. Isolated fracture of the styloid process of the ulna is rare, and is caused by direct violence. The fragment

can always be distinctly felt underneath the integument, and since it can easily be grasped, its proper reduction can always be accomplished. To retain it well, an adhesive plaster pad must be applied over the fractured area. The dressing must immobilize the elbow as well as the wrist for at least two weeks,

Fig. 61.—Fracture of the lower end of the ulna in a boy of twelve years, showing soft callus formation (three weeks after the injury).

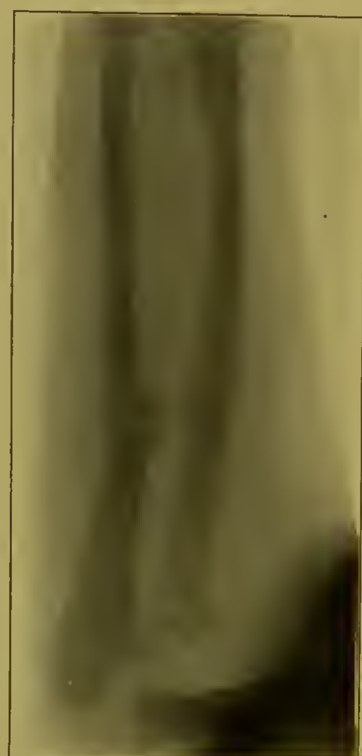

Fig. 62.—Fracture of the diaphysis of the ulna. Slight displacement in a child of two years (two days after the injury).

since there is great tendency to displacement—an event that might be followed by the formation of pseudarthrosis.

Fracture of the styloid process of the ulna occurs, in the great majority of cases, in connection with fracture of the lower end of the radius.

The *treatment* is essentially the same as that for fracture of the lower end of the radius combined with fracture of the styloid process of the ulna. (See p. 154.)

V. Fissure of the capitulum ulnæ is found in connection with the classic fracture of the lower end of the

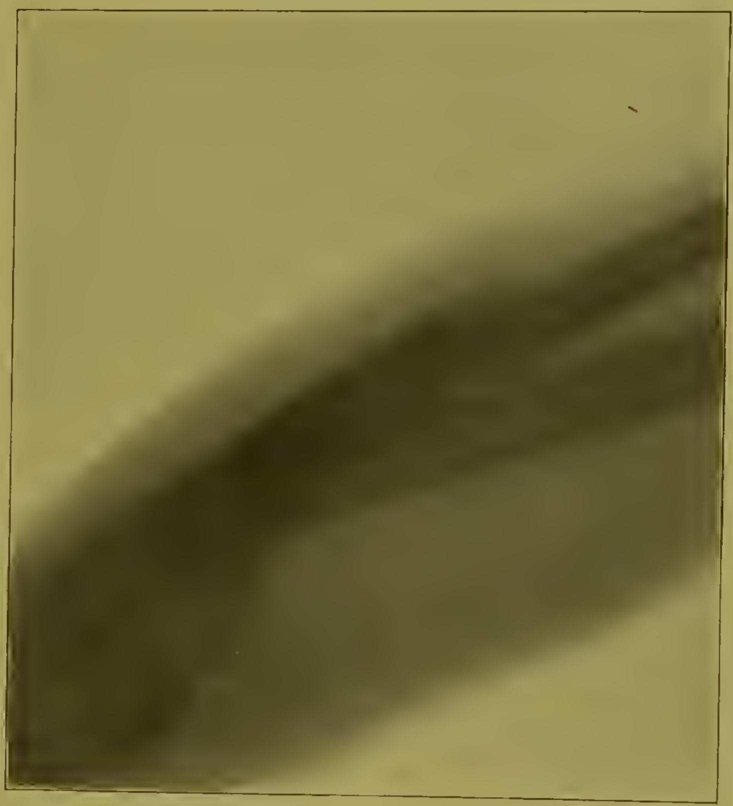

Fig. 63.—Fusion of radius and ulna nine weeks after fracture of the ulna, rendering supination impossible, in a man of thirty-three years. (Compare Fig. 69.)

radius, as demonstrated first by the author.* (Fig. 85.) This phenomenon was never recognized until the Röntgen rays taught its presence. In the author's cases the line of infraction has always been transverse.

* See "The Röntgen Rays in Surgery," "International Medical Magazine," May, 1897.

The *symptoms* of its presence are so insignificant that it can be well understood why in former times no attention was ever paid to it.

2. Radius.—1. **Fracture of the head of the radius** (Figs. 64 and 65) is generally caused by indirect violence (fall upon the outstretched hand when in pronation). Direct violence (blow upon the head of the radius) produces it but exceptionally. Sometimes

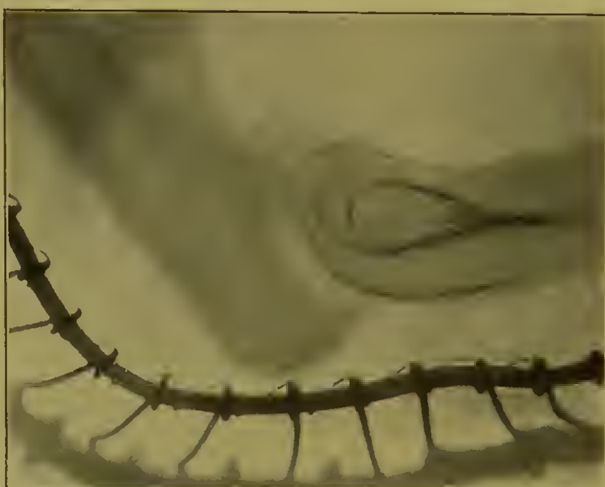

Fig. 64.—Fracture of the head of the radius in a man thirty-two years of age; skiagram taken through plaster-of-Paris wire splint twelve hours after the injury. There was considerable outward displacement, which was believed to have been reduced after the dressing was applied, but the skiagram, taken after the dressing was completed, showed that displacement was still present. (Compare Fig. 65.)

there is only an infraction, in which case the diagnosis could not be made without the aid of the Röntgen rays. Contusion or distortion is usually suspected in such cases. Its character is naturally intra-articular. It is, like the fracture of the radial neck, observed as an isolated fracture as well as in combination with one of the other bony elements of the elbow.

If there is a complete fracture, abnormal mobility is always present, and there is also intense pain at the

seat of the fracture. Crepitus is perceived by turning the hand alternately in pronation and supination.

The *treatment* consists in the application of an immobilizing dressing in the position of extreme flexion, in order to relax the biceps muscle, a pad being attached over the fractured area. Immobilization must be kept up for at least three weeks, in order to avoid the recurrence of displacement. Premature contraction of the biceps muscle might sep-

Fig. 65.—Fracture of the head of the radius. Same case as that shown in figure 64. Displacement corrected in the extended position (four days after the injury).

arate the replaced fragments. If the fragments should not be properly retained in place, the production of extensive adhesions might demand resection of the radial head.

Sometimes small fragments separated from the cartilage remain detached, and act like foreign bodies, so as to disturb the function of the elbow. In such cases their removal may be indicated. In the rare event of laceration of the radial nerve, neurorrhaphy is indicated.

Epiphyseal separation occurs in infants and young children in a small number of cases. It is caused by holding their hands up or by swinging them. The treatment is the same as that of fracture of the radial head.

II. Fracture of the neck of the radius is still rarer

Fig. 66.—Fracture of the neck of the radius in a man thirty years of age. Moderate deformity, but small longitudinal splinter adhering to the lateral surface by fibrous tissue, causing functional disturbance (nine years after the injury).

than that of its head. Its etiology is the same. The *signs* are also similar, the only difference consisting in the impossibility of turning the radial head to and fro during pronation and supination in cases of fracture of the neck. A bony projection may also be found in the latter event.

The *treatment* is the same as that of the fracture of the radial head.

The radial nerve may become lacerated by a splinter of bone (Fig. 66), in which case removal of the splinter, under the use of the Röntgen rays, is indicated.

The same nerve may become embedded in a callus-mass (Fig. 67), in which event it must be freed by chiseling off the abundant callus.

III. Fracture of the shaft of the radius (Fig. 68) is caused by violence, either direct (blow upon the arm) or indirect (fall on the hand). It is rare.

The *signs* consist in displacement, abnormal mobility,

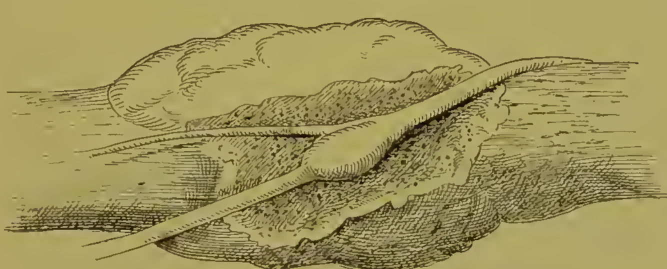

Fig. 67.—Radial nerve thickened and embedded in callus-tissue (after Ollier).

and localized pain. Crepitus is perceived whenever pronation and supination are exercised.

The *treatment* consists in thorough reposition and the application of an upper and a lower splint in supination. Immobilization should be extended over the elbow as well as the wrist. If reposition is imperfect, the interosseal space may be filled up by callus formation, and a consequent fusion with the ulna would occur, which would render pronation and supination impossible. (Fig. 69; compare Fig. 63 as counterpart.) In such event separation by operative interference would be indicated.

IV. Typical fracture of the lower end of the radius (erroneously called Colles' fracture) is the most frequent fracture type, and is supposed to form at least eighteen

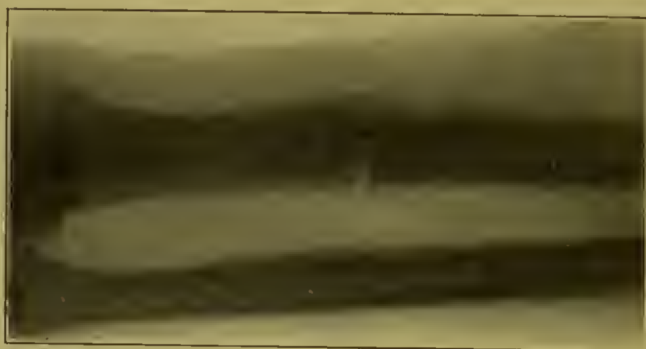

Fig. 68.—Fracture of the shaft of the radius without displacement in a woman twenty-eight years of age. Slight callus formation (seventeen days after the injury); also showing signs of well-united fracture of the lower end of the radius, sustained six years earlier.

Fig. 69.—Fracture of the shaft of the radius in a man thirty-six years of age, showing considerable displacement, the upper fragment riding upon the lower, thereby causing functional disturbance (one year after the injury).

per cent. of all fractures. In the author's estimation it figures with twenty-two per cent. It is caused by a fall upon the hand while in dorsal extension. The very strong ligamentum carpi volare profundum being

more resistant than the spongious end of the bone, it is evident why, as first demonstrated by Nélaton (Fig. 70), that structure never breaks, and that a radial fracture can be the only result.

In no fracture type have the Röntgen rays disclosed so many errors as in this much-disputed fracture. It can safely be maintained that in most cases skiagraphy has revealed conditions that were not expected and that have required the original diagnosis to be more or less modified.

Fig. 70. — Fracture of the lower end of the radius and of the styloid process of the ulna. The ligamentum carpi volare is much strained, but is still cohering.

The question most frequently asked of a surgeon: "How do you treat Colles' fracture?" or "Do you use long or short splints? Do you prefer the plaster-of-Paris dressing or splint, or are you fond of Dumreicher's, Roser's, Schede's, Braatz's, Gordon's, Kölliker's, Moore's, Carr's, Bond's, Middeldorpf's bilateral, or the old pistol splint of Nélaton? Are you in favor of immobilization or of early motion?" etc., show that fracture of the lower end of the radius is regarded as of a constant type, uniformly characterized by the fracture of the bone about an inch above the articulation, and followed by a silver-fork-shaped deformity of the wrist. This point of view is inadequate and erroneous.

It has been found that the anatomic aspects of the various forms of fracture of the lower end of the

radius differ in fact more than those of any other fracture; and it is self-evident that such variants are by no means of indifferent importance in respect to treatment. For a simple fracture, for instance, and for a Y-shaped intra-articular fracture, different therapeutic means must necessarily be sought. Again, the varying relations of the fracture of the radius to its fellow, the ulna, are of great practical importance.

Since March, 1896, when the author first began to skiagraph all his cases of fracture and suspected fracture, until recently, he has observed fracture of the

Fig. 71.—Chondro-epiphyseal separation in an infant.

lower end of the radius sixty-two times. In a number of cases fissure of the ulna coexists, as was first reported by him. Another surprising feature is that simultaneous fracture of the styloid process of the ulna has been found in a great number of cases, a complication that was formerly supposed to be of extremely rare occurrence.

It is but natural that our views should be changed by fuller clinical experience and anatomic observation. Without undervaluing the great work of our surgical masters before the Röntgen era, the rays furnish the

most convincing proof of the necessity of modifying their interpretations of this injury. Thus, having regard to old experience as well as to information gained but recently, the author has tried to classify those different forms of this much-disputed fracture that appear to be most characteristic, and must accordingly demand different therapeutic measures; and if we bear in mind the frequency of fractures of this type, the importance of the discussion will be evident.

In classifying the different varieties of fracture of the lower end of the radius it is essential to distinguish:

(*a*) Epiphyseal separation.

(*b*) Fissures (infractions).

(*c*) Complete fractures.

(*d*) Incomplete fractures.

(*e*) Fractures of the lower end of the radius combined with infraction or fracture of the head of the ulna.

(*f*) Fractures of the lower end of the radius combined with fractures of the styloid process of the ulna.

All these different varieties may be extra-articular as well as intra-articular.

(*a*) *Epiphyseal separation* of the lower end of the radius shows the same symptoms and has to be treated on the same principles as the complete fracture.

The bicycle enthusiasm is responsible for a greater frequency of the separation of the lower epiphyses in young adults.

In very young children there are real *chondro-epiphyseal* separations (Fig. 71), in which the epiphyseal cartilage is sharply severed from the osseous end of the diaphysis; while later, at the age of between four-

Left Hand. *Right Hand.*

Fig. 72.—Fracture of the lower ends of both radii in a lad seventeen years of age. The left hand shows considerable sideward displacement of the radial fragment toward the ulna. There is also osteo-epiphyseal separation of the styloid area of the ulna. The right hand shows osteo-epiphyseal separation of two radial fragments. The large radial fragment is not displaced, while the small one is entirely severed. The ulna shows osteo-epiphyseal separation (five days after the injury).

teen and seventeen, *osteo-epiphyseal* separation is observed, the fracture-line not being strictly limited to the epiphyseal cartilage, but extending to the diaphysis. The latter variety occurs more frequently than the first one, which is extremely rare. (See Fig. 72, right hand.) There is a great tendency to rapid union in children. Sometimes, however, the growth of the radius becomes arrested, notwithstanding the accomplishment of a perfect union.

Fig. 73.—Fissure of the lower end of the radius, one inch above the epiphyseal cartilage, in a boy fourteen years of age (one week after the injury).

Fig. 74.—Fissure of the lower end of the radius in a man thirty-four years of age. Small splinter protruding toward the ulna (eight hours after the injury).

(*b*) *Fissures* (*infractions*) (Figs. 73, 74) are extra-articular as well as intra-articular, and are far more frequent than was supposed before the discovery of the Röntgen rays. In former times fissure has doubtless been often treated as distortion or contusion, especially when only small splinters were broken off. (Fig. 74). No displacement being present, it is easily understood why such injuries often healed under any treatment. Sometimes these cases, not being recognized in their true light, gave a better prognosis

than those which were properly diagnosticated, but in which the limb had been immobilized during too long a period.

The line of infraction in these cases is either transverse (as in Fig. 73) or longitudinal (Fig. 74), so that the bone appears as if divided into halves; or it is irregular in shape, generally resembling a star. In such cases the bone is divided into several still cohering portions.

The *signs* are severe pain and slight swelling at the seat of infraction. Abnormal mobility and crepitus being absent, the diagnosis of contusion or distortion is obviously often made.

Treatment.—No displacement being present, no reduction is required. This explains why the results in these cases are nearly always good, no matter what sort of treatment is employed. In fact, if they are treated by a quack, whose ignorance leads him to treat the injury as a sprain, with an ointment, a poultice, or "faith," a better result may sometimes be obtained than by the learned surgical neophyte, who, after a most erudite diagnosis, immobilizes the joint for a long period in his zeal to keep the imaginary fragments together. Of course, no deformity will result, but adhesions may form in the neighboring joint or in the sheaths of the tendons, and the wrist may become stiff and immobile. In such a case a patient who was not treated at all—in other words, whose hand was not immobilized, so that he could constantly use it—would, in fact, escape unpleasant consequences.

In cases in which the Röntgen rays prove the existence of a fissure beyond a doubt, a wire splint which is slightly bent downward is to be applied at the

flexor side of the arm, where it reaches from the tip of the fingers to the elbow, the downward bent portion of the splint being attached to the palm of the hand. If there is much swelling, the dressing must be kept moist with Burow's solution. (Compare pp. 48 and 67.)

After three or four days, when the swelling has subsided, this long splint must be removed, and a bracelet, consisting of a piece of moss-board, is applied instead. The width of this bracelet should be about four inches, its middle corresponding to the wrist. This appliance immobilizes the wrist sufficiently, and at the same time it permits enough motion to counteract the formation of adhesions in the sheaths of the tendons. The patient carries his hand in a sling in such a manner that the ulnar margin rests on it. Thus, free motion of the hand is permitted. The patient is told to move his fingers, as in playing the piano. The author also finds it very useful to advise the patient to grasp marbles of moderate size and to roll them around in the palm of the hand. Patients generally are willing to keep these marbles in their pockets and play with them while reading or conversing or walking around. If motion is thus kept up constantly, massage treatment as well as forcible motion can be dispensed with in this fracture type.

(*c*) *Complete fractures*, the most frequent varieties of fractures of the lower end of the radius, must also be subdivided into intra-articular and extra-articular.

The *intra-articular* variety is the most important, since it is always complicated with more or less grave injuries to the joint-surfaces. (Fig. 75.) The line of fracture is generally oblique, but sometimes nearly longitudinal. The tendency to displacement

is particularly marked in this form. Still, abnormal mobility, and crepitus accordingly, are but seldom noticeable. Since there is generally a well-marked extravasation, which may extend even over the sheaths

Fig. 75.—Complete intra-articular fracture (Y-shaped) of the lower end of the radius, in a woman of forty years, showing lateral as well as median displacement of fragments (two hours after the injury).

of the tendons, palpation is rendered extremely difficult and uncertain. Massage has to be employed early, in order to remove the extravasation, when sometimes the margins of the severed fragments can be grasped. Further valuable signs of fracture, like

deformity, caused by the displacement, may also be veiled on account of the extravasation. It goes without saying that another sign of fracture, severe local pain, is never absent.

From a consideration of all these points it becomes evident that a detailed diagnosis of this type is possible only by the aid of the Röntgen rays, which show us, also, just how the displaced fragments are to be reduced. Sometimes reduction can be done properly only when an anesthetic is employed. Forcible extension for the purpose is contraindicated because it would increase the traumatic synovitis always present in this variety. The severed fragments are readjusted best by gentle grasping manipulations. An adhesive plaster pad is applied over the displaced fragment after reduction is accomplished, and moderate pressure until slight agglutination has taken place. This may be expected after a few days. Then further pressure can be dispensed with. Otherwise the treatment is the same as that of the extra-articular variety. (See p. 148.)

Among all the different types of fractures of the lower end of the radius the intra-articular is the most serious. Only the continuous control, by the aid of the Röntgen rays, of the proper situation of the fragments will give good results.

The *extra-articular* complete type is the best known among the varieties of this fracture. (Fig. 76.) Having been first described by Colles, it is called Colles' fracture in this country as well as in England. It is generally transverse, and so has the character of a supracondyloid fracture. Its seat is generally about 3/4 of an inch above the articulation, where the compact

A. B.

Fig. 76.—Extra-articular fracture of the lower end of the radius (Colles' fracture) in a young man of twenty years. A. Showing inward displacement and impaction (twelve days after the injury). B. Displacement reduced (three weeks after the injury).

Fig. 77.—Complete extra-articular fracture of the radius (Colles' fracture), showing bayonet-shaped deformity (anterior view).

tissue of the diaphysis passes over into the cancellated spongiosa.

Signs.—Displacement always being present in this type, the deformity is highly characteristic. In most cases the direction of the displacement is upward, so that there is a dorsal prominence. In such cases the shape of the deformed wrist resembles that of a bayonet or a fork, for which reason Colles' fracture has also been called silver-fork fracture (*displacement à la fourchette*). (Figs. 77, 78.) By thus being upwardly dislodged, the epiphyseal portion is brought into slight supination, while the diaphysis is in decided pronation. The epiphysis being in very close connection with the ulna, the latter is slightly pushed toward the ulna if the ligamentous connection between the radial fragment and the ulna remains intact. This phenomenon finds its conspicuous expression in the lateral prominence of the styloid process of the ulna.

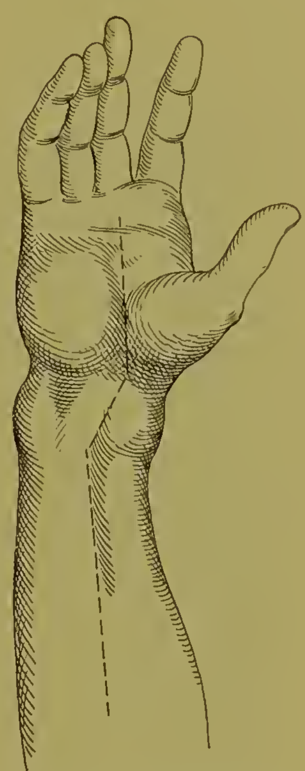

Fig. 78.—Complete extra-articular fracture of the lower end of the radius (Colles' fracture) showing bayonet-shaped deformity (posterior view).

Sometimes the tendency of epiphyseal displacement is toward the opposite side or downward, and the deformity appears accordingly in that direction. (Compare Figs. 79, 80, 81.) In the first case the direction of the displacement was never recognized in the pre-Röntgen era. Abnormal mobility

is always present to a greater or lesser extent, and consequently there is always crepitus.

In examining the patient a firm support must be obtained for the injured hand, the latter being kept down on a plane by an assistant, and the epiphyseal fragment being grasped. Inspection invariably detects the characteristic abnormal prominence, while palpation is

Fig. 79.—Downward displacement in extra-articular fracture of lower end of the radius in a man thirty years of age (two days after the injury). A. Anterior view. B. Lateral view.

often able to outline the shape of the fragment. The local pain is generally severe.

In the rare event of impaction of the epiphyseal end into the upper end of the radius, abnormal mobility and crepitus are absent.

Treatment.—The first requirement, accurate reduction, may be carried out with little difficulty by forced extension, the hand being grasped as in a firm handshaking, with downward pressure by the surgeon's

thumb, while counterextension is used on the forearm, which is flexed rectangularly. If an assistant is at hand, the surgeon grasps four fingers with his left, and

Fig. 80.—Extra-articular fracture of the lower end of the radius in a woman forty-five years of age, showing sideward displacement (one day after the injury).

Fig. 81.—Extra articular fracture of the lower end of the radius in a woman forty-five years of age. Skiagram of same case as figure 80, showing fragment displaced toward the ulna, thus causing the slight projection.

the thumb with his right, hand, while the assistant uses counterpressure at the elbow. (Fig. 83.) If this procedure should fail, anesthesia must be employed.

Keeping the fragments well adjusted in a proper position is quite difficult sometimes. The author has, however, always been able to secure this by very simple methods. A long adaptable wire splint (see p. 97) is applied while forced traction is made; the splint reaches at the flexor side of the arm from the tip of the fingers to the elbow. If the direction of the displacement is *upward* (silver-fork shape), a pad of adhesive plaster is attached to the dorsal integument above the fragment. Then a short, narrow splint of wood is applied on the dorsal aspect of the arm, reaching from the metacarpophalangeal joint to four inches above the wrist, and is kept pressing down by the application of a gauze bandage.

Fig. 82.—Extra-articular fracture of the lower end of the radius in a woman forty-five years of age. Immobilization in plaster-of-Paris dressing after the reposition of the displacement.

If the tendency of the displacement is *downward* (Fig. 79), the same procedure is carried out in the opposite manner, the wire splint being applied on the dorsal and the wooden splint and pad on the palmar side of the arm.

If the displacement be *sidewise* (Figs. 80, 81), which is most marked when there is a simultaneous injury of the ulna, the immobilization must be carried out on entirely different lines. The adhesive plaster pad must then be applied laterally to the fragment, two

long, narrow wooden splints being used at the same time. One of these splints, being a little broader than the diameter of the bone, begins at the metacarpo-phalangeal joint of the thumb, and the other at the same point of the little finger. Both extend up to the elbow, the same as the long wire splint. If there should be any displacement in the opposite direction, the pad must be applied on the ulnar side. No dorsal splint is used in this variety. After the dressing is finished, the skiagram verifies the proper position of the fragments. In case the tendency to displacement

Fig. 83.—Forcible reduction.

can not be overcome, a plaster-of-Paris dressing is applied (Fig. 82), while forcible extension and counter-extension are used. (Fig. 83.) Whether the position of the fragments is correct should be ascertained by the rays after the plaster-of-Paris dressing is applied. (Fig. 84.)

If there be much swelling, wet applications may be advantageously used by pouring Burow's solution upon the gauze bandage, the wire splint permitting penetration of the fluid. (Compare pp. 48, 67.)

If after the lapse of a week agglutination of the frag-

ments is obtained and no deformity is evident, then the soft tissues must receive consideration. It is only then that short splints are in order. They consist of well-padded pieces of wood, extending from the metacarpo-phalangeal joint up to the middle of the forearm. After another week a bracelet, such as is recommended for the treatment of simple fissure (p. 142), is so applied as to permit of free motion of the fingers. The patient is also told to move his fingers as in playing the piano,

Fig. 84.—Extra-articular fracture of the lower end of the radius in a woman thirty-five years of age; skiagram taken through the plaster-of-Paris dressing (two weeks after the injury).

also to use the marbles, as described in the treatment of the fissure.

After the third week massage treatment is indicated, active as well as passive motion of the joint being employed at the same time. The results of these simple methods are just as good as, if not better than, those obtained by the numerous most complicated apparatus often advised for the same purpose. If all the points of these manipulations dictated by simple

common sense are observed, and if their proper execution is certified by the skiagram, surgical clinics will no longer furnish so much testimony of deformities and functional impairment following fracture of the lower end of the radius.

In cases of severe functional disturbance of the joint produced by the agglutination of the fragments in a displaced position the author has repeatedly succeeded in reducing the deformity by osteotomy. In every case the functional result has been very satisfactory.

(*e*) *Fractures of the lower end of the radius combined*

Fig. 85.—Extra-articular fracture of the lower end of the radius combined with irregular fissure of the head of the ulna ½ of an inch above the epiphysis in a woman twenty-nine years of age (one day after the injury).

with fissure or fracture of the head of the ulna (Fig. 85) are of moderate frequency. This combination was entirely unknown before the Röntgen discovery. It was the privilege of the author to call attention to its existence first.* Since that time he has observed it in eleven per cent. of his cases of fracture of the lower

* See "The Röntgen Rays in Surgery," "International Medical Magazine," May, 1897.

end of the radius. This surprising experience was corroborated by Kahleyss.*

In case of fissure of the ulna no displacement is present and the symptoms are essentially the same as those of the complete fractures described on page 148.

In the much rarer event of complete fracture of the ulna the symptoms of sideward displacement are well pronounced. This combination is the main cause of the impairment of supination and pronation.

The treatment is the same as that of complete frac-

Fig. 86.—Fracture of the lower end of the radius combined with fracture of the styloid process of the ulna in a man thirty-eight years of age (two days after the injury).

tures connected with sideward displacement (see p. 150), sideward pressure by attaching an adhesive plaster pad over the ulnar fragment after reduction being well kept up.

(*f*) *Fracture of the lower end of the radius combined with fracture of the styloid process of the ulna* (Fig. 86) is extremely frequent. In the author's cases this com-

* "Beitrag zur Kenntniss der Fracturen am unteren Ende des Radius," "Deutsche Festschrift für Chirurgie," 12. November, 1897.

bination represents thirty-two per cent. of all cases of fracture of the lower end of the radius. In this variety the radio-ulnar joint is always more or less involved.

The treatment is the same as that of the complete fractures connected with sideward displacement, sideward pressure by attaching adhesive plaster pads over

Fig. 87.—Excessive callus formation after extra-articular fracture of the radius in a boy fifteen years of age, followed by considerable disturbance in pronation and supination (four months after the injury).

Fig. 88.—Excessive callus formation after extra-articular fracture in a girl sixteen years of age. No functional disturbance (three weeks after the injury).

the fragments after reduction being rigidly maintained. In obstinate cases the resection of the process is sometimes indicated.

In case of functional disturbances caused by excessive callus formation osteotomy has to be resorted to. (Fig. 87.) Simple deformity not connected with any functional disturbance would not indicate chiseling off the callus. (Fig. 88.)

Deformities causing severe disturbances of the function of the wrist may be corrected by performing osteotomy in the radial fracture-line. Sometimes, in addition, a wedge must be exsected from the ulna in order to permit of perfect reposition.

If rotation is impossible, the head of the ulna should be resected. The author's experience comprises four such cases, in persons of thirty-three to forty years, in

Fig. 89.—Fracture of radius and ulna in a boy nine years of age. Angular displacement not reduced; abundant callus formation beginning (six weeks after the injury).

which osteotomy gave gratifying results. Adults who must support themselves by the work of their hands should invariably be subjected to radical operative correction. Only aged persons should be exempted.

3. Fracture of Radius and Ulna Together.—Simultaneous fractures of radius and ulna are of moderately frequent occurrence and are caused by direct as well as by indirect violence. Especially in early childhood, where the typical fracture of the radius is

rare on account of the soft condition of the epiphyseal end of that bone, a fall on the outstretched hand produces the fracture of both bones. Sometimes there is only an infraction, if children are exceptionally concerned.

The centers of both diaphyses are most liable to fracture. It is only by direct violence (falling of heavy objects, gunshot wounds) that the other portions of the bones of the forearm become fractured.

The *signs* are generally well marked. Displacement always being present, the bones form a slight anterior or posterior angle. (Fig. 89.) If, as it happens in children, there are still cohering portions of periosteum and bone, the displacement may be insignificant. (Fig. 90.) There is intense pain, abnormal mobility, and loss of function. Sometimes the displacement is so great that the fragments overlap. Then considerable shortening of the arm will be

Fig. 90.—Fracture of radius and ulna (green-stick variety) in a boy twelve years of age, showing cohering periosteal and osseous portions. No ulnar and only slight radial displacement (two days after the injury).

noticed. (Fig. 91.) Sometimes one of the two bones is only fissured; then there is but little displacement, as a rule, in the other. (Fig. 92.)

The *treatment* consists in the application of long wooden splints, after reduction has been accomplished by forcible extension and counterextension. The very wide, well-padded splints (one on the flexor and one on the extensor side) must reach from the metacarpus up above the elbow, the hand being kept in supination.

Fig. 91.—Fracture of radius and ulna in a man thirty-nine years of age, showing overlapping of fragments (eight weeks after the injury).

This position prevents fusion of both bones (ossification of the ligament). After the lapse of a week a plaster-of-Paris dressing can be applied, while the elbow is in the rectangular position. After three weeks, massage treatment, active and passive motion, especially rotatory manipulations, are instituted.

In intrauterine fracture of the radius and ulna wiring of the bones has to be resorted to. In the case illustrated by figure 93 (see also Figs. 1, 2) the author has succeeded in uniting the fragments in this manner.

Pseudarthrosis of the antibrachium is rarer than that of the humerus. It is also caused by the intervention of muscular tissue. It is especially the upper third whose anatomic conditions seem to favor it. If one portion of the arm is in pronation and the other one in supination, the separation of the fragments may become so great that the upper end of the radial fragment unites with the lower one of the ulna. Such conditions can be remedied only by osteotomy. If the

Fig. 92.—Fracture of the radius combined with fissure of the ulna—slight axial displacement of the radius—in a man twenty-two years of age (ten days after the injury).

radius is concerned at its upper third, its deep situation causes considerable technical difficulties for operation

If radius and ulna grow together laterally, so that a bridge is formed that fills the interosseal space, supination is prevented. Compare figures 63 and 69 as counterparts. Then the division of the bridge by the use of a chisel or a Gigli wire saw is indicated, the arm being immobilized in supination afterward.

In *compound fractures* the question of amputation

often arises. As previously emphasized in Part I of this book, conservative principles should be upheld to the utmost. Sometimes under the most unfavorable circumstances—extensive comminuted fractures and necrosis, laceration of the flexor and extensor muscles, necrosis of a large skin-portion—still fairly good function of the extremity is finally obtained.

Loose bone-splinters must be removed and sharp edges should be cut away with bone-shears. Lacerated tendons must be trimmed and carefully united

Fig. 93.—Intrauterine fracture of radius and ulna, united by osteorrhaphy, in a boy of three months. Radial wire extracted; ulnar wire still *in situ* (four weeks after operation).

with thin formalin catgut. Necrotic skin-portions must be exsected. Skin-grafting should not be attempted before there is a normally granulating surface. As long as there is much reaction, a wire splint should be applied in vertical suspension, which method permits of the permanent application of an antiseptic lotion. (Compare section on Compound Fractures, p. 67.) When the swelling has subsided and the suppuration has become scant, a moss splint or a fenestrated plaster-of-Paris dressing should be chosen.

HAND AND FINGERS.

Fracture of the bones of the hand and fingers are classified as follows:

1. Fracture of the carpus.
2. Fracture of the metacarpus.
3. Fracture of the phalanges.

Fracture of the carpus is extremely rare and is always caused by direct violence (fall of heavy objects).

Fig. 94.—Supracondylar fracture of first metacarpus of the little finger, showing inward displacement (thus also resembling dislocation), in a man twenty-eight years of age (two weeks after the injury).

The ligaments connecting these bones being very strong, the displacement is insignificant, and therefore the fracture often escapes notice unless a skiagram is taken.

Abnormal mobility and crepitus naturally being absent, pain and functional disturbance are the main signs. This fracture is generally combined with severe injuries of the soft tissues.

The *treatment* consists in applying a palmar wire splint. Immobilization is properly combined with the

application of antiseptic lotions, especially if there be simultaneous injuries to the soft tissues. In the event

Fig. 95.—Fracture of right fourth metacarpus, showing displacement, in a man thirty years of age (two days after the injury).

Fig. 96.—Dorsal dislocation of the thumb (outer view) in a boy of twelve years (four weeks after the injury).

of a compound comminuted fracture of a carpal bone, its removal is indicated.

After the lapse of ten days massage treatment and active and passive motion are in order.

Fracture of the metacarpus (Fig. 94), especially of the first metacarpal bone, is very common, and is also

Fig. 97.—Dorsal dislocation of the thumb. Skiagram of figure 96.

Fig. 98.—Lateral dislocation of thumb in a girl eight years of age (six weeks after the injury).

produced by direct violence. The interosseous muscles pulling the upper fragment downward, some slight

displacement can always be noticed. (Fig. 95.) There is also abnormal mobility, crepitus, local pain, and swelling. As the Röntgen rays have demonstrated, a large

Fig. 99.—Dorsal dislocation of the second phalanx of the thumb in a woman thirty years of age (sixteen months after the injury).

Fig. 100.—Supracondylar fracture of the first phalanx of the little finger in a lad of twenty years (two days after the injury).

number of alleged dislocations and contusions are, in fact, separations of the phalangeal epiphyses in childhood.

The treatment is essentially the same as that of the fracture of a carpal bone, the only point to be specially

considered in this injury being that an adhesive plaster pad should be placed on the palm at the seat of the fracture.

Massage must be commenced early. In the exceptional case of considerable displacement wiring of the fragments may come into consideration.

Fracture of the phalanges is nearly always caused by direct violence (the fingers being caught or held in a door, etc.). Exceptionally, it is produced by indirect violence (fall on the fingers or overextension during wrestling, etc.).

The *signs* are typical, and, in fact, so apparent that they should hardly need description. Still, fracture is sometimes confounded with dislocations. As to contradistinction, compare figures 96, 97, 98, and 99.

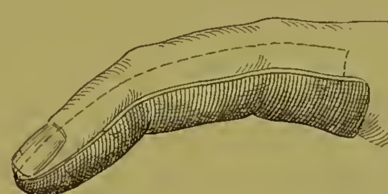

Fig. 101.—Splint for phalangeal fracture (after Hoffa).

The *treatment* consists in keeping the fragments well immobilized by small splints of wood or pasteboard (Fig. 101), after thorough reduction is accomplished. The splints are to be fastened by starched gauze bandages. Union is generally perfect in two weeks.

If the fracture be comminuted or compound, extreme conservatism should prevail. It is surprising how often a shattered phalanx is entirely restored to its function under thorough aseptic precautions. The severed fragments being removed, sometimes all that is left of the phalanx is represented by a thin bony fragment; nevertheless, this may develop into a useful phalanx again, provided enough periosteum is left in its place.

FRACTURES OF THE PELVIS AND THE LOWER EXTREMITY.

PELVIS.

Fractures of the pelvis represent less than one per cent. of all fractures, and are similar to those of the skull and thorax, inasmuch as they occur in an osseous ring, irregularly composed of several bones: namely, the os ilii, the os pubis, the os ischii, and the sacrum

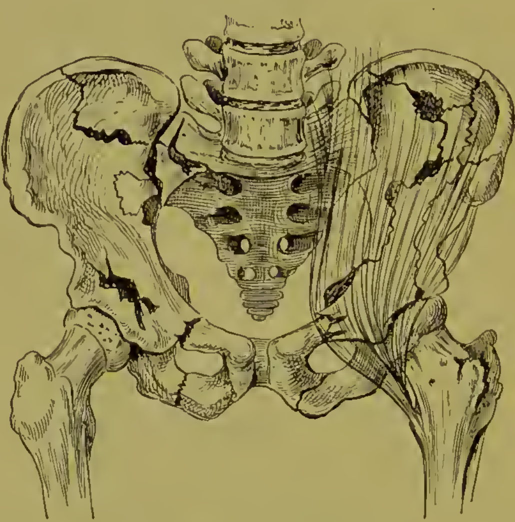

Fig. 102.—Fracture of pelvis, fragments boring into ileopsoas muscle (after Hoffa).

and coccyx. They concern either one of these bones individually or the pelvic ring as a whole. (Fig. 102.)

They are generally caused by direct violence, as, for instance, by a heavy weight falling upon the pelvis, or by the patient falling from a high point, or by his being crushed between the buffers of two railroad-cars while they are being coupled, or by the passage of a wagon-wheel across the lower abdomen.

In the first event—*fracture of an individual pelvic*

bone—palpation will always reveal separation of at least a single fractured bone-portion. Abnormal mobility, displacement, and consequently crepitus, are always present. The abdominal organs are but seldom injured.

The *treatment* consists in reposition as far as is possible, and immobilization by applying a long splint extending from the external malleolus to the axilla. (Compare Fig. 103.) Union in a deformed position, while, of course, undesirable, is seldom followed by any functional disturbance.

Fractures of the **pelvic ring** are always to be re-

Fig. 103.—Long splint applied during extension, in fracture of the pelvis or the neck of the femur.

garded as of importance, since they are generally accompanied by simultaneous injuries either of the abdominal viscera or of the urethra, the sciatic nerve, or the femoral vessels.

The *signs* consist in ecchymosis, localized pain, which is severely intensified on pressure, inability to lift the lower limb, and marked displacement. In all cases of suspected pelvic fracture the rectum and urethra must be carefully explored also. In trying to press both iliac bones together an intense circumscribed pain is produced, which may direct attention to the point of fracture.

Laceration of the urethra as well as abdominal injuries are treated upon general surgical principles. In urethral injuries permanent catheterization should be employed. It is the significance and extent of these concomitant injuries that determine the course of this dreaded fracture type.

The best *treatment* consists in the application of a plaster-of-Paris dressing surrounding the abdomen, pelvis, and thigh (Fig. 116), or in the application of a long splint. (Fig. 103.) Extension also sometimes proves useful. (Fig. 10.)

THIGH.

Fractures of the thigh represent about six per cent. of all fractures. They are divided into those of the upper end, those of the diaphysis, and those of the lower end of the femur. In adults they generally occur in the lower, and in aged persons in the upper, end, while in children the middle third is most frequently involved. They occur, however, in any part of the bone in children.

Fracture of the Upper End of the Femur.—Fracture of the upper part of the femur concerns either its head or neck or the trochanteric region. Anatomically, it is to be divided into epiphyseal separation of the upper end of the femur, in fracture of the neck (intra- and extracapsular), the isolated fracture of the trochanter major, and the infratrochanteric fracture.

I. Epiphyseal separation of the upper end of the femur occurs before the twentieth year, and is extremely rare. The epiphysis being intra-articularly situated, it is obvious that it is but seldom reached by an injury. As

a rule, this fracture is produced by a sudden wrench or sprain.

The *signs* consist mainly in abnormal mobility, intense local pain, and soft crepitus. There is also shortening and elevation of the trochanter major above Nélaton's line. It is easily confounded with dislocation, hip-disease, or infantile paralysis. It is often overlooked until the patient commences to walk. Ununited fracture may cause lameness.

The *treatment* is the same as that of a fracture of the femoral neck. In ununited fracture operative interference is indicated. (Compare section on Wiring the Bones, p. 70.)

II. Fracture of the neck of the femur seldom occurs before the fiftieth year of life, and may be caused by direct as well as by indirect violence (fall upon the hip, blow upon the trochanter major). The line of fracture is either in the intertrochanteric line or at the femoral head, or between these points. Its direction is either transverse or oblique to the axis of the neck. Accordingly, intra- and extracapsular fractures of the neck of the femur are distinguished, analogous to the fractures of the anatomic and surgical necks of the humerus.

(*a*) *Intracapsular fracture* (Fig. 104) is most frequent in aged persons, a prevalence that is explained by the senile changes at the angle of the thigh-bone. While in earlier life the angle of the neck to the shaft is still oblique, it becomes rectangular in elderly people. Thus the bone becomes more fragile, so that it may fracture even after trifling injuries, such as, for instance, simply falling on a carpet.

The line of fracture is transverse and is generally

indentated, so that impaction is greatly favored. Sometimes there is only infraction.

The *signs* of intracapsular fracture are but little marked if there be infraction or impaction, so that no displacement is produced. The only signs would then be the local pain and functional disorder of the leg, so that contusion of the hip may be thought of.

Fig. 104.—Intracapsular fracture in a man fifty-five years of age, showing absence of osseous union; head appearing to be free in the acetabulum. Fibrous union permits of limited amount of motion (two years after the injury).

In such cases elucidation by the Röntgen rays is urgently required.

If there is displacement, the signs are very distinct. Then the leg is rotated outward and is shortened to the extent of at least an inch. Crepitus and pain are also then present.

If the fracture be not caused by a fall upon the hip,

ecchymosis, if present at all, will be insignificant. The pain is severe on the seat of fracture and increases if the thigh is flexed. Crepitus is absent.

Treatment meets with great difficulties. These are caused, in the first place, by the poor chance of approximating the fragments, the diastasis of which is increased by the intracapsular blood extravasation. The upper fragment, the sole connection of which is the ligamentum teres, has but a poor arterial supply. The osteoblasts, which regenerate new bone-tissue from the spongious portion of the bone only, are scant, since there is merely a cartilaginous coat; and callus formation is consequently poor. The most favorable outcome to be looked for is therefore a superficial approximation of the fragments by a few fibrous bands.

Another and still more important difficulty is presented by the general condition of the patients, who are usually aged, and therefore inclined to hypostatic pneumonia when condemned to a prolonged sick-bed. It is especially here that the ambulatory plaster-of-Paris dressing shows its great advantages. (See p. 43.)

This dressing is applied at once after the integument is well oiled. Reposition is made after the leg is surrounded first by an ordinary plaster-of-Paris dressing from the metatarsus up to the knee. It is then easy to reduce the fragment by pulling on the foot, while counterextension is exercised on the pelvis. The patient's trunk and pelvis are elevated throughout the time when this procedure is carried out. Now around the tubera ossis ischii and the trochanter a seating-ring is formed, which, after being hardened, is connected with the dressing of the lower end. This is accomplished by many turns of plaster-of-Paris ban-

dages, below which a thin wooden fiber for firmer support is interposed. (Fig. 6.)

Patients are sometimes able to go about on crutches as early as two days after the fracture was sustained. It is needless to call attention to the fact that in each case the circulation is likely to be well kept up and the danger of hypostasis in the lungs is often counteracted.

If for any reason the ambulatory dressing can not be applied, Buck's extension (see Fig. 10), in connection with a long extension splint (see Fig. 103), must be employed. Great care should then be taken that no pressure is made upon the sacrum, where decubitus may become detrimental.

The position of the upper parts of the body must be frequently changed and the patient should be advised to sit up in bed frequently and to inspire deeply in order to avoid circulatory stasis.

Where reposition is found to be impossible, and the displacement is of considerable extent, uniting the fragments with ivory pegs has repeatedly been suggested. While the idea of this procedure is irreproachable from a theoretic standpoint, it can not be indorsed, because it has shown unsatisfactory results in practice. In several cases it was also followed by fatal consequences.

It is self-evident that in cases of infraction and impaction, where naturally there is no displacement, the results are in general most satisfactory.

(*b*) *Extracapsular fracture of the neck of the femur* (Fig. 105) is generally produced by direct violence (fall upon the hip or blow on the trochanter major). The direction of the fracture is usually in the intertrochanteric line.

The fracture may be incomplete, in which event it is only the posterior cervical portion that is clearly divided, while the thicker anterior portion shows infraction only.

Much more frequently the fracture is complete, in which case the trochanter as well as the head of the

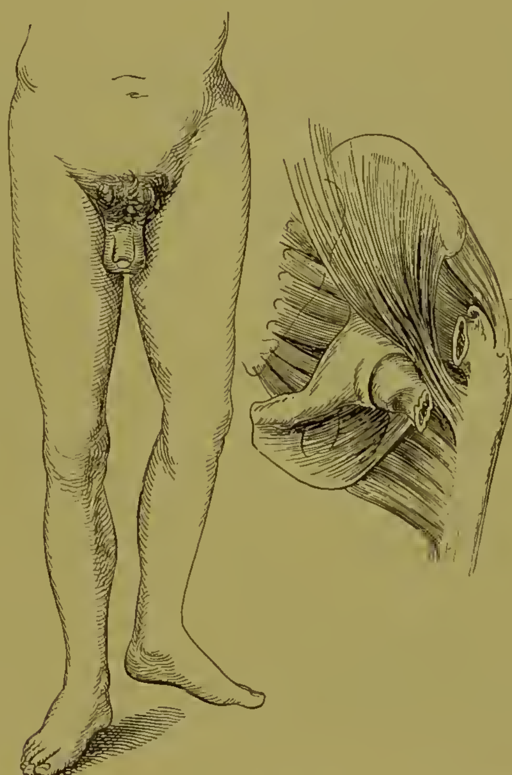

Fig. 105.—Extracapsular fracture of the neck of the femur (after Hoffa).

femur may be so involved that there are several distinct fragments.

The *signs* are ecchymosis, shortening, and outward rotation. In impaction (Fig. 106) the shortening seldom exceeds 1½ inches; but if there is no impaction, the shortening may amount to four inches. Another important sign—the higher situation of the trochanter

major—can be elicited by measuring the distance from the anterior superior spine to the knee, which is found shorter than that of the uninjured extremity.

If there is any displacement, crepitus can be detected invariably. Local pain, tenderness, and swelling are also seldom absent. Ordinarily, there is entire loss of function; but in impacted extracapsular frac-

Fig. 106.—Extracapsular fracture of the neck of the femur in a woman twenty-six years of age; considerable functional disturbance (two months after the injury).

tures it has repeatedly been observed that the patients were able to walk a short distance.

The *diagnosis* of this fracture type may become difficult if neither shortening nor rotation of the leg be present, and the case may be mistaken for one of simple contusion. Looking for crepitus in such cases seems, as a rule, to be inadvisable; since the rotatory

manipulations necessary for eliciting it might be apt to separate the impaction—an event which would at least make a bad matter worse. And even in cases in which shortening and rotation were well marked, dislocation instead of fracture has been diagnosticated. It is true that a certain similarity to iliac dislocation exists, but the latter can be always excluded, for the reason that the femoral head can not be found outside of the acetabulum. It should furthermore be considered that in a fracture of this kind the patient is unable to elevate his leg by active flexion ; while in dislocation passive motion would be arrested to a much higher degree than in fracture.

In summing up the main points of differentiation it should be considered that in *dislocation* the femoral head can be palpated in the buttocks. In dislocation there is also a moderate amount of resistance when motion is made, while in fracture there is little or none. In dislocation the upper portion of the hip-joint is flattened, while in fracture there is no change of the normal contours. If the trochanter appears widened and enlarged, the chances are that the patient fell upon the trochanter, which fact would point to a fracture. In old age fracture is the rule.

Bony union, while exceptional in the intracapsular type, is the rule in the extracapsular variety, callus proliferation generally being abundant. Sometimes the callus is so rich that free articular motion becomes impeded. (Fig. 107.)

Union generally becomes perfect in six weeks, after which the function of the extremity is seldom found to be disturbed, even if shortening to the extent of an inch has occurred.

Fig. 107.—Impacted extracapsular fracture of the neck of the femur in a man fifty-eight years of age (three years after the injury), causing considerable functional disturbance on account of the excessive callus proliferation around the seat of the fracture, especially around the major trochanter.

The principles of *treatment* are the same as those for the intracapsular fracture of the neck of the femur.

III. Isolated fracture of the trochanter major (Fig. 108 *a* and *b*) is always produced by direct violence, and is of rare occurrence. By being pulled backward and upward by the gluteal medius and minimus muscles the trochanter appears considerably displaced. The trochanter major is also sometimes separated in persons under the age of seventeen years.

The *signs* are sometimes insignificant, and may

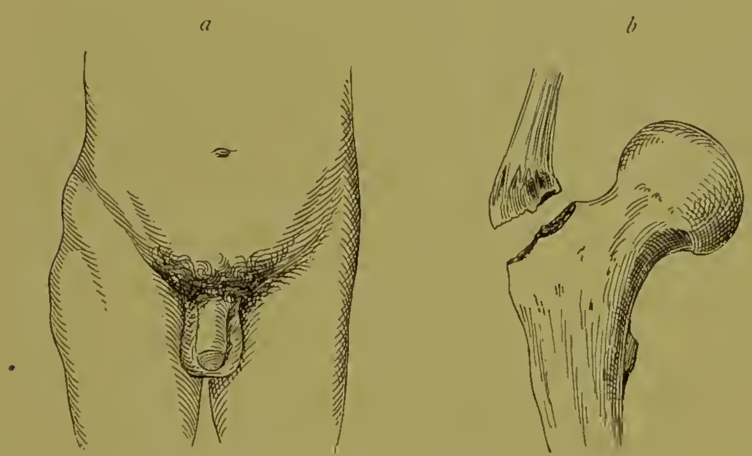

Fig. 108.—Isolated fracture of trochanter major. *a*. Exterior view; *b*, showing diastasis (after Hoffa).

point to a contusion, since the function of the leg is little, if at all, disturbed; inward rotation of the leg being possible by the action of the tensor fasciæ latæ muscle, and outward rotation by that of the obturatores, gemelli, and quadratus femoris. There is, of course, no shortening such as occurs in fracture of the femoral neck. Flattening of the trochanteric area is often noticed. The displaced fragments being nearly always palpable, differentiation from simple contusion should be easy.

The *treatment* consists in immobilization of the leg between two sand-bags in outward rotation and abduc-

Fig. 109.—Spiral infratrochanteric fracture in a boy of twelve years (fourteen hours after the injury), showing but little sideward displacement.

tion, while the hip and knee are slightly flexed. In this position reduction of the displaced fragment is

accomplished to the nearest extent possible. An adhesive plaster compress, to be kept *in situ* by an adhesive plaster strip, should be applied above and behind the fragments.

In children a large abdominofemoral dressing, consisting of plaster-of-Paris, is recommended. (Fig. 115.)

IV. Infratrochanteric fracture (Fig. 109)—that is, fracture just below the trochanter—is caused either by indirect violence (torsion of the body while falling down), causing a spiral-shaped line (Fig. 109), or by direct violence (blow or fall), which would cause a transverse line. It is prevalent among the hard-working classes, and generally concerns adults.

The *signs*, besides those found in ordinary fractures, are the tilting upward of the upper fragments by the ileopsoas and glutæi muscles, which are inserted below the trochanter. This characteristic phenomenon explains why the upper fragment is sometimes put into a right angle to the femoral axis. In rotating the femur it will be found that the trochanter does not go along with the motion, abnormal mobility being found only below the trochanter.

The *treatment* requires reposition and extension in a flexed position; otherwise it is treated after the same principles as the fractures of the neck of the femur.

Fracture of the Diaphysis of the Femur.—Fractures of the diaphysis of the femur are far more frequent than those of the neck. Of all femoral fractures, which figure at six per cent. among all fractures, they represent seventy-one per cent., while those of the neck amount to twenty-nine per cent. only. They are caused either by direct or indirect violence or by mus-

cular action. Most of these fractures are caused by a downfall from a considerable height. The line of fracture is generally oblique, if the middle and upper thirds of the shaft are concerned; but in the lower third a transverse direction is the rule. Sometimes a longitudinal fracture-line branches off from the transverse one into the knee-joint (T-fracture). These transverse

Fig. 110.—Infratrochanteric fracture in an infant of ten months. No effort at reposition was made during the first three weeks after the injury. Union took place with considerable deformity and slight functional disturbance.

fractures are especially frequent in children, who may sustain them in consequence of comparatively slight violence. Rickety children have a special predilection for this variety. The prognosis is very good in childhood, union generally being perfect in from three to four weeks.

Simultaneous injuries to the femoral artery and vein

are by no means rare complications of this fracture type.

The *signs* of fracture of the diaphysis are, first of all, ecchymosis, intense pain, and entire loss of function. With the exception of the rare cases where the periosteum remained partly intact, or where indentation of

Fig. 111.—Fracture of the diaphysis of the femur in an infant six months of age, showing slight riding of fragments (two days after the injury).

the fractured ends keeps them fixed together, much deformity is always present. (Fig. 111.) This is caused by the considerable degree of displacement more or less characteristic of this injury. It is naturally followed by another conspicuous symptom: namely, the extreme shortening, which in some cases amounts to as much as six inches. Generally, the lower fragment

is rotated outward and pulled upward and to the inner and outer side of the upper one. In fracture of the upper third the upper fragment is drawn upward and outward by the action of the ileopsoas and glutæi muscles, while the lower one is drawn inward and upward by the action of the adductor muscles. Thus riding of

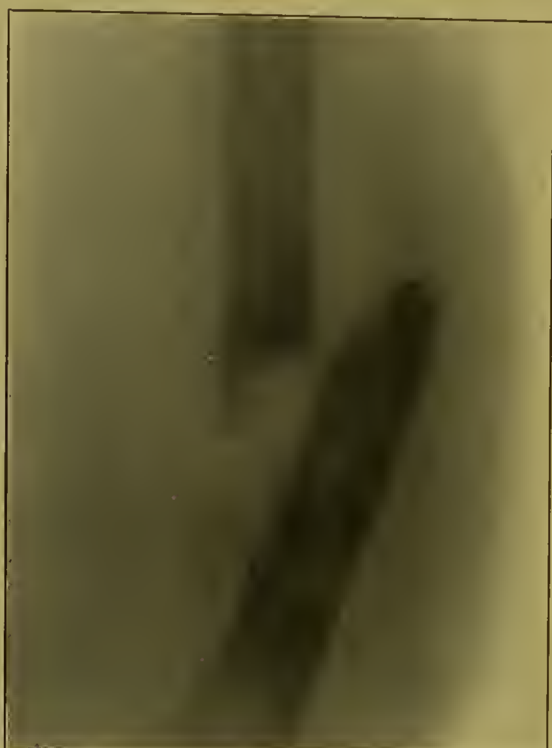

Fig. 112.—Typical oblique fracture of diaphysis at the upper third of the femur, showing considerable displacement and intervening of muscular tissue, in a boy seven years of age (twenty-four hours after the injury).

the fragments is produced (see Fig. 112), so that they show an angle. (Also compare Fig. 114.)

In the middle third the upper fragment is drawn before the lower one and outward from it, if the line of fracture is situated above the insertion of the adductor muscles; but if it occurs below that point, the upper fragment is directed forward and inward.

The same principle as to displacement applies to all fractures of the *lower third*. It scarcely need be said that such extensive displacement is always accompanied by abnormal mobility, and that crepitus is never absent. The shortening of the leg is always considerable. The rough edges of the upper fragment are generally easily palpable above the patella, where it often pierces the tendon of the quadriceps muscle, while the lower fragment is felt in the popliteal space. It is also obvious that in T- or Y-shaped fractures of the lower third of the shaft synovitis, due to extravasation of blood in the knee-joint, is likely to be caused.

In case of indentation of the fragments, an occurrence that is prevalent in children, displacement, abnormal mobility, and crepitus are naturally absent, but there is always present another well-marked symptom: namely, a pronounced angle at the seat of the fracture. The same rule applies to subperiosteal fractures of the shaft.

It may be regarded, therefore, as an exception when fractures of the femur can not be diagnosticated by simple inspection. Consequently, the patient can usually be spared the painful manipulations required for eliciting abnormal mobility and crepitus at the time of the first dressing.

Union is generally perfect in six weeks. (Fig. 113.) In oblique fractures slight shortening is seldom avoidable; but in transverse fractures the normal length of the leg can always be preserved. In case of considerable shortening, caused by vicious union (Fig. 114), osteotomy is indicated.

Compound fractures of the shaft are so grave that before the time of antisepsis they showed a mortality-

Fig. 113.—Union in fracture of the middle of the femur in a boy of seven years (nine weeks after the injury). In spite of the sideward displacement causing deformity, there is neither shortening nor functional disturbance, which is especially due to the abundance of callus formation.

rate of sixty per cent. Nowadays, they usually heal without reaction under the auspices of thorough asepsis. (See p. 51.) It is only in compound fractures produced by a very heavy weight (locomotive,

Fig. 114.—Vicious union of fracture of femur, showing riding of fragments, in a man fifty-two years of age (nine weeks after the injury).

large artillery) that life is jeopardized. In such cases, or when large vessels and nerves are lacerated, amputation offers the only life-saving chance.

The *treatment* consists in reposition by tension and counterextension. Indisputably, a normal position of

the fragments is attainable if the anterior superior spine and the inner margin of the patella and of the great toe are in a straight line. For keeping the fragments in this position Buck's extension (from fifteen to twenty-five pounds; in children a pound for each year), supported by coaptation splints, is the securest procedure. These splints, preferably four altogether, should be placed around the fractured area. They may consist of wood and must be well padded, and should be fixed to the thigh by adhesive plaster. Adhesive plaster strips should next be carried around the knee-joint up to the point of fracture. Counterextension is easily accomplished by elevating the foot of the bed.

In children good results can be attained by vertical extension. Although the final results reported of this treatment are excellent, the author is unable to persuade himself to resort to a method that is sure to cause so much annoyance to the patient. A plaster-of-Paris dressing applied around the abdomen and thigh while forcible extension and counterextension are exercised, and supported by coaptation splints, gives the same good result (Fig. 116); while at the same time the children can be carried around in this dressing, and are therefore but little confined. Even in the quite unnecessary event of pressure-gangrene of the integument of the thigh no serious consequences need be feared, since the muscular layers protecting the femur are extremely thick. (Fig. 115.)

In adults the ambulatory dressing is advisable. It should be applied from two to seven days after the injury is sustained, under the conditions set forth in Part I, where also the technic of application is discussed.

The principle of the ambulatory dressing is based upon that of the old Thomas splint. (See Fig. 6.) The dressing is supported by the tuber ischii, so that the pelvis is carried and the leg simply hangs down.

Fig. 115.—Showing application of abdominal plaster-of-Paris dressing in fracture of the diaphysis of the femur in a girl fifteen months of age. The discoloration is caused by copal varnish.

The modus operandi of application is the same as that in fracture of the neck of the femur.

In case of union in a slightly displaced position of the fragments edema extending as far as to the toes

is often noted. Weeks after perfect consolidation has taken place the patient may limp, and a cyanotic appearance, a sense of frigidity, and cold perspiration are likely to disturb his equanimity. Hot soda baths (a handful of washing soda to a pail of very warm water), hot fomentations overnight, electricity, and

Fig. 116.—Abdominal plaster-of-Paris dressing applied while extension and counterextension are exercised, the patient resting on a hip- and shoulder-rest.

massage are indicated in this condition. Massage is especially useful if there be muscular atrophy.

If union has taken place in a *faulty position*, the function of the lower extremity is greatly disturbed. It is the angular type of deformity that is prevalent in fractures of the femur, and that is always followed by considerable shortening, sometimes to the extent of five or six inches, as in the case illustrated by figure 114.

In children the fresh callus yields to forcible bending. Thus, without refracturing the femur correction of the deformity under anesthesia is often possible. In adults correction by such a procedure is impossible, consolidation once having taken place. Then, if the function of the extremity is not considerably disturbed, a high shoe may compensate the shortening. But if there is much disturbance of function, osteotomy should be resorted to for radical correction.

Refracturing the deformed bone by pressing it against the edge of the table is permissible in suitable cases. It has all the advantages of the subcutaneous fracture type; but in most instances the degree of correction obtained is insignificant, the shortening especially being but little affected.

In performing osteotomy the incision should be made on the convexity of the deformed area, which must be well exposed by an elevator. Then the line of union of the fragments is severed by means of a strong broad chisel. In old fractures it will often be necessary, in order to straighten the extremity, to resect a wedge from the vertex of the deformed angle. After a large moss dressing has been applied the extremity is put in permanent extension. (See p. 49.)

In *pseudarthrosis* osteotomy is always indicated, the modus operandi being practically the same as for faulty union, as previously described. The incision must be long, and should be made longitudinally on either the outer or the anterior surface of the thigh. The periosteum must be saved in its entirety, and should therefore also be incised in the longitudinal direction only. After all the intervening tissue has been pushed aside or eventually removed, the bone-ends are fresh-

ened and united with strong silver wire. Under the most minute aseptic precautions, osteotomy, be it done for faulty union or for pseudarthrosis, is an absolutely safe operation. (Compare aseptic rules, page 52.)

Ankylosis (which is generally due to inflammatory processes of long duration) produced by comminuted fractures extending into the knee-joint is easily relieved by forcible motion under anesthesia, provided it exists for a short period only and is of a fibrous nature; but if it be of an osseous character, any attempt at forcible motion may be followed by fatal consequences.

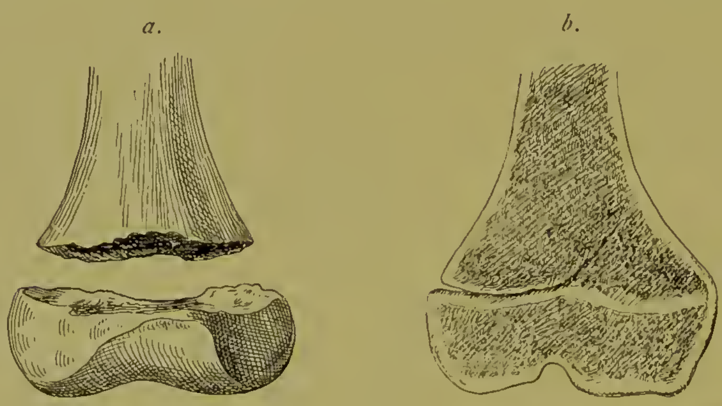

Fig. 117.—Epiphyseal separation of lower end of femur. *a*. Complete; *b*, incomplete.

Only an osteotomy performed according to the rules set forth in Part I of this book could remedy this condition. In cases of long standing, however, where other pathologic changes of the knee-joint have developed (fibrous degeneration, atrophy, etc.), and where the function of the extremity is not too seriously impaired, operative interference is better dispensed with. (Compare Fig. 119.)

Epiphyseal separation of the lower end of the femur (Fig. 117) also deserves mention. It is either complete

(Fig. 117 *a*) or incomplete (Fig. 117 *b*), is not infrequent at about the age of sixteen years, and is mainly observed in boys. Its principal cause is, however, overtraction during an obstetric operation. Sometimes it is also produced by excessive violence, as, for instance, by having the limb entangled in a revolving wheel. As a rule, it shows some displacement. There

A. B.

Fig. 118.—Normal knee-joint. A. Anterior view in a boy twelve years of age; note the epiphyseal cartilages; patella represented by a faint shade only. B. Side view in a man thirty years of age.

is always abnormal mobility and soft crepitus. The epiphysis can generally be palpated in its displaced position. In the knee-joint extravasation to a greater or less extent is always found. Pressure and ulceration may lead to secondary hemorrhage, and thrombosis may favor gangrene. The principles of treatment are the same as those for the fracture of the lower

third of the femoral shaft. In case the epiphysis can not be replaced, excision is indicated.

Intra-articular separation in the knee still remains to be mentioned. It consists either in a rupture of the semilunar cartilages or in the severing of a piece of the femoral end.

Rupture of the semilunar cartilages is caused by extensive rotation of the femoral end while the knee is flexed (foot-ball game).

The *signs* are the presence of a movable body in the joint, which disappears during flexion and becomes noticeable during extension.

The *treatment* consists in reposition, if possible, and immobilization by a plaster-of-Paris dressing in extension. In obstinate cases extirpation of the severed cartilage is indicated.

Intra-articular severing of a piece of the femoral end is caused by extreme compression of the bones of the knee while the latter is in flexion. The severed piece moves freely in the joint (joint-mouse).

The *signs* are similar to those of the rupture of the semilunar cartilages.

The *treatment* consists in the immediate removal of the cartilage.

To appreciate the significance of the various fracture types within the sphere of the knee-joint, it is necessary to understand the peculiar anatomic relations of the knee.

In the first place, it must be considered that the knee-joint consists of the femoral condyles, the tibial head, and the patella, which form three different articulations: viz., one between each tuberosity of the tibia on one side and between each femoral condyle on

the other, and one between the femur and the patella. These articulations permit of extension, flexion, and a moderate degree of rotation. The tibiofemoral articulations are true condyloid joints, while the femoropatellar articulations are only of a partly arthroidal character, their mutual joint-surfaces, in fact, not being adapted to each other. (Fig. 118.)

PATELLA.

Fractures of the patella amount to two per cent. of all fractures, and are far more frequent in the male than in the female. They seldom occur after the age of fifty, and never in young children.

Fracture of the patella may be produced by direct as well as by indirect violence. If produced by direct violence (blow on the anterior bone-surface, fall on the anterior portion of the knee-joint, kick of a horse), the soft tissues in the immediate neighborhood are generally more involved than the patella itself. The line of fracture may be transverse, oblique, or longitudinal, and its character may be compound or comminuted. (Fig. 120 *a* and *b*.)

If produced by indirect violence (muscular action), a transverse fracture is always caused, contraction of the quadriceps muscle fixing the patella while extreme flexion in the knee takes place. So, for instance, if a patient attempts to save himself from falling while making a misstep, by simple reflex the quadriceps is suddenly fixed and the knee-joint is kept in extreme flexion.

The signs of fracture of the patella are, in the first place, the separation diastasis of the fragments (Figs.

121 and 122), the upper one being drawn upward by the action of the quadriceps muscle. (Fig. 123.) The sulcus produced by the diastasis is sometimes as wide as two fingers' breadth.

The posterior patellar surface forming a part of the knee-joint, it is obvious that there is always more or less considerable extravasation in the knee-joint.

It is usually taught that the disturbance of function

Fig. 119.—Bony ankylosis of knee in a woman thirty-five years of age.

may not be excessive so long as the patient is in an upright position, but that as soon as an attempt at walking is made, the patient would invariably tumble down. But the author's experience shows cases in which, in spite of considerable diastasis, patients were able to walk considerable distances without apparent discomfort. (Compare remarks on Fig. 123.)

If the injury be examined just after the fracture is sustained, crepitus is generally produced, but afterward the intervention of blood-clots between the fragments prevents its production.

If the periosteal coat of the patella is preserved intact, there is no displacement, and consequently no crepitus. The same rule holds good in fracture of a small portion of the patella.

It is evident that in case of extreme extravasation, when, for instance, the prepatellar bursæ are also well filled up, palpation of the fragments becomes so very

Fig. 120.—Types of comminuted patellar fracture.

difficult that the injury may be mistaken for contusion of the knee-joint.

With few exceptions union in *transverse fracture* of the patella, if not sutured, fails to become osseous, fibrous bands filling up the space between the fragments. This is obviously due to the diastasis. In such an event the function of the joint is impaired—inability to perform extension and thorough flexion, considerable atrophy of the muscles of the leg, and a greater or less degree of knock-knee being the predominating symptoms. While those who follow a light occupation may not be incapacitated, and may

do well by wearing a knee-cap, workingmen may be deprived of their means of making a living by such impairment.

In the *longitudinal* (compare Fig. 120 *a*) or *comminuted* fracture type, where no muscular contraction produces any diastasis of the fragments, the union is always osseous.

Cases of extreme extravasation show a great tendency to the formation of serous intra-articular effusion (hydrarthrosis).

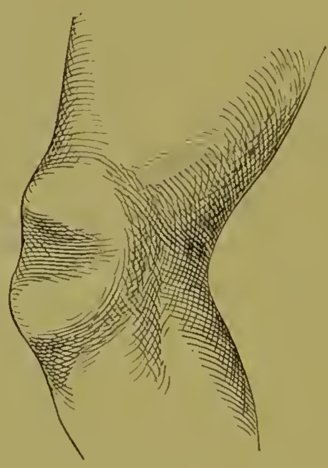

Fig. 121.—Fracture of patella. Outer view.

The **treatment** in *longitudinal* or in *partial fractures* of the patella consists in bringing the fragments into apposition and in proper immobilization by splints or a plaster-of-Paris dressing. Sometimes reposition can be accomplished only after the blood extravasation has been removed by massage. If the exudate be considerable, its puncture and its removal by irrigation with a hot normal salt solution may become necessary.

This must be done under the most rigorous aseptic precautions.

Regarding the immense importance of such precautions, the following points may be emphasized in this connection:

In the first place, it must be considered that an in-

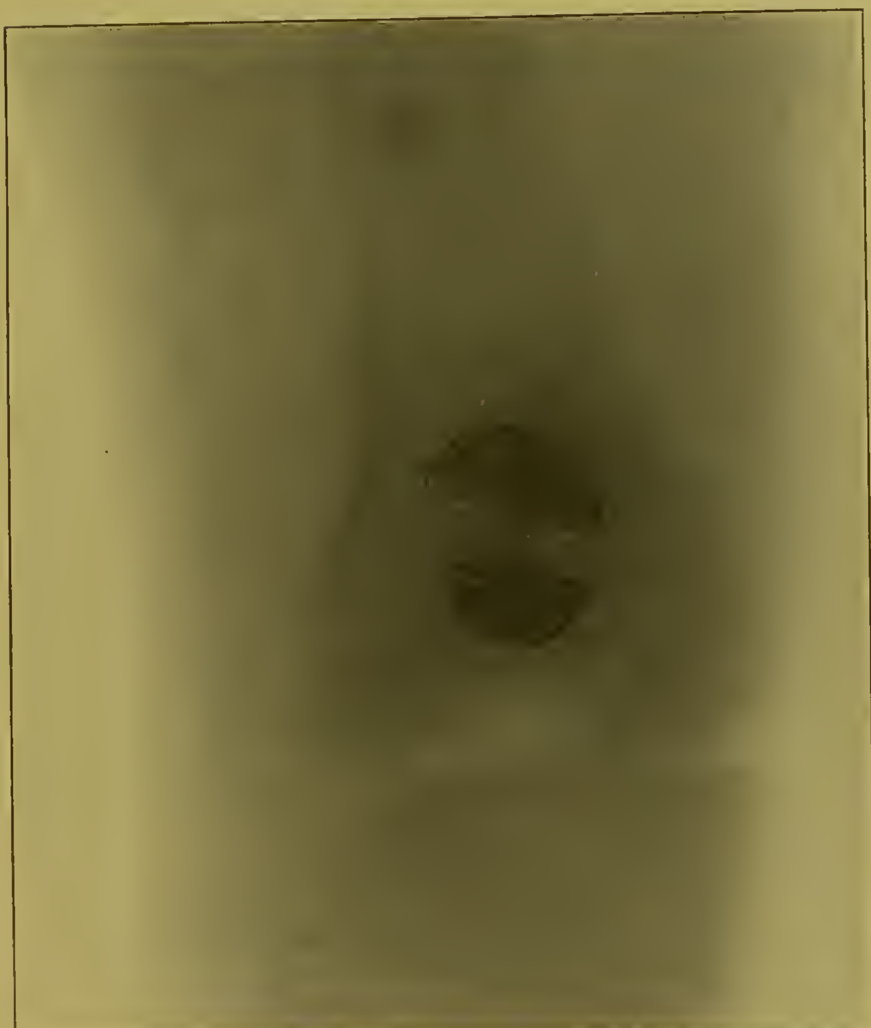

Fig. 122.—Fracture of patella, showing moderate degree of diastasis, in a woman of thirty-three years (sixteen hours after the injury).

jection has the dignity of a surgical operation, and should therefore be viewed from a strictly surgical

standpoint. Especially should it be preceded by the same preliminary precautions: viz., sterilization of the puncturing apparatus (trocar or aspirator), of the hands of the surgeon, and of the region to be punctured.

As far as the first point—the apparatus—is concerned, it can be safely maintained that ideal asepsis

Fig. 123.—Fracture of patella in a man twenty-six years of age, who walked around for one week without being treated. Motion was but slightly arrested; pain almost absent (eight days after the injury).

has become an established fact, because all objects that stand boiling well can be rendered aseptic in boiling water, a means accessible everywhere. There is no more excuse for a surgeon to claim that "the poor circumstances of the patient's surroundings did not permit of aseptic precautions." Water, fire, and a boiling-pot can be obtained in the poorest hut, so that the puncturing trocar can easily be sterilized.

Since syringes are so constructed that they stand boiling in a soda solution, the same applies to them. Ordinary hypodermic syringes should never be used for the purpose of aspiration, because they do not stand boiling without being injured, nor do they draw thick fluid. Another objection to them is that their thin needles break easily if they have to be pushed deep down into resistant tissues.

As far as the hands of the surgeon and the region to be punctured are concerned, the general rules emphasized in connection with the treatment of compound fractures are referred to. As mentioned on page 56, that enemy of thorough asepsis, intracutaneous bacteria, should nŏt be underrated in connection with the question of puncturing. It is evident that in perforating the skin the sterilized puncturing needle must come in contact with the deep skin-bacteria, which are sheltered by the follicles of the integument, and must thus become a carrier of infection. It is an undeniable fact that these intracutaneous bacteria can not be destroyed by any chemic or mechanical means of disinfection. Still, a great deal can be done to lessen the danger of infection by this source. Fortunately, we possess a splendid permeating antiseptic in the tincture of iodin, which, if liberally used, reaches the bacterial shelter—the glands. It is true that, as the bacteriologic experiments of the author have shown, not all intracutaneous bacteria are destroyed by the tincture, cultures having developed on artificial soil. But they failed to develop on an unfavorable soil. It is safe, therefore, to assume that if the surface of the skin is cleaned according to the aseptic rules laid down on page 52, and the region of the area to be

punctured is painted with iodin tincture, a sterilized instrument in sterilized hands will hardly carry bacteria into the joint-cavity.

In *transverse fractures* of the patella showing *little or no diastasis*, a plaster-of-Paris dressing is applied according to the principles laid down for fracture of the olecranon. (See p. 125.)

While the displaced fragment is tightly grasped and pushed downward by the fingers of an assistant, the dressing is applied. The limb is best put in the hyper-extended position, while the patient sits in bed half upright. The turns of the bandage are conducted around the pressing fingers, so that at last a wall is formed around the digital impressions, which includes the reduced fragments after the plaster sets, and becomes so firm that a return of the fragments proves to be impossible.

But if there is *considerable diastasis*, *wiring of the fragments* can not too strongly be advocated, since the performance of this simple operation is void of danger in the hands of a surgeon who is master of the principles of asepsis. Whatever has been said of the dangers of this operation applies more to the surgical novice, who does not properly understand asepsis, than to aseptic surgery itself. When it is considered that without such operation union becomes only fibrous, and that in the course of time the originally fibrous bands become stretched by the action of the quadriceps muscle, so that active extension of the knee-joint becomes impossible,—in other words, that the patient becomes a cripple for life,—we should not refrain from exposing the patient to the trouble of this operation, which guarantees an absolute cure.

Complicated manœuvers, like boring holes into the fragments, etc., can not be too strongly condemned, since simply conducting a large needle armed with silver wire around the fragments secures their perfect apposition. The needle must be introduced at the upper end into the quadriceps tendon above the patellar margin and through the ligamentum patellæ

Fig. 124.—Wiring of the patella: placing the silver wire around the fragments. Each of the two black semilunar points represents a patellar fragment. The white egg-shaped area between the patellar fragments belongs to the anterior surface of the external femoral condyle.

on the lower margin of the lower fragment. (Fig. 124.) The silver wire is twisted above the middle of the fracture line, its ends protruding at last through the suture line of the integument. (Fig. 125.)

A semilunar incision should be made from one epicondyle to the other, just above the insertion of the

ligamentum patellæ. Thus a convex flap is formed, which is dissected backward. The fractured area is then fully exposed, and the intra-articular blood extravasation can be freely reached.

An iron-clad principle, especially referring to this operation, is, "Hands off the joint!"

For the consolation of such surgeons as are afraid

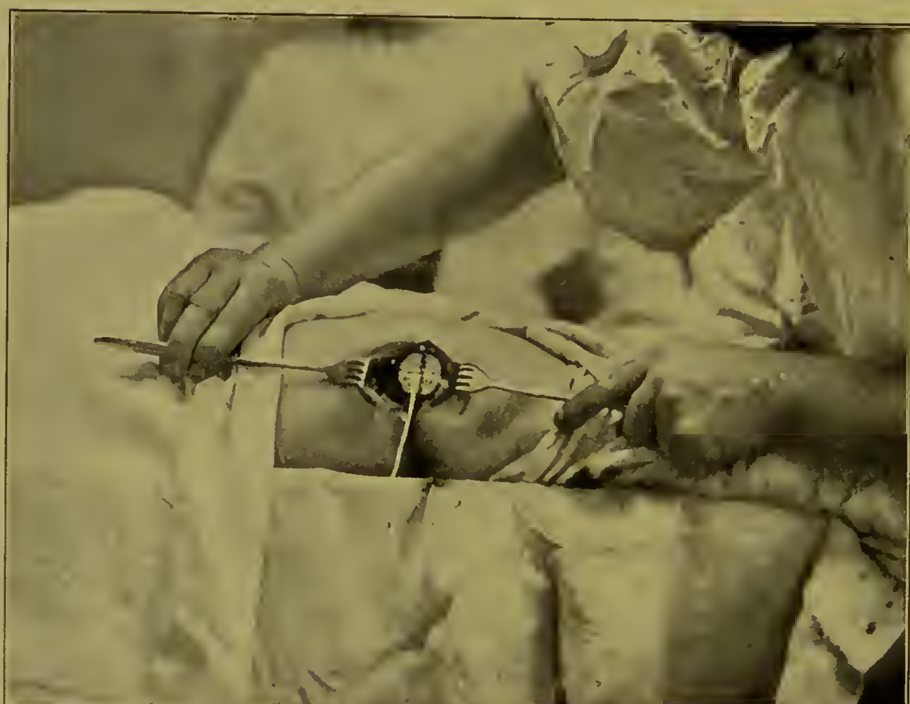

Fig. 125.—Patellar fragments (Fig. 124) united by a silver wire suture.

of the aseptic state of their own fingers it may be said that there is no need for coming into contact with any portion of the field of operation with their fingers or hands. The needle can be carried through with the aid of a needle-holder and the twisting, which in itself tends to bring the fragments together, can be done with a forceps. The blood-clots can be removed by powerful irrigation with a hot sterile salt solution.

For powerful and thorough irrigation, intended for the mechanical removal of such material as may be apt to offer a favorable soil for the development of bacteria (tissue-shreds, blood-clots), an operating-table (Fig. 5) that is provided with pans is of great convenience.

Fig. 126.—Wire broken three weeks after the operation, the nervous patient having jumped out of bed during the night. Immediate recurrence of diastasis.

After the suturing (preferably done with boiled formalin catgut) is completed, either an ordinary wound dressing, supported by a large moss splint, or a fenestrated plaster-of-Paris dressing (the fenestra being created by holding a sterilized glass over the wound—

see Fig. 5) is applied. The wire suture is carefully removed after three weeks. Then the knee is well immobilized for two or three weeks longer, and the patient is allowed to walk about in this dressing.

The wire must be very strong, for there is risk of its breaking if the patient be restless. (Fig. 126.) The operation can be performed immediately after the accident, but may just as well be deferred for a few days if extravasation is abundant.

In view of the absolute certainty of success in this operation, the principle of which was advanced by one of the greatest surgical geniuses of all time, Volkmann, it appears rather strange that procedures like the treatment with Malgaigne's hook, which remind one of the relics in the torture chambers of Nuremberg, still find their devoted partizans.

Compound fractures of the patella are treated after the same principles as are set forth in Part I. (P. 51.)

In the event of atrophy of the quadriceps muscle, which is extremely frequent after the non-operative treatment of the patellar fracture, faradization and massage are indicated for a long time.

LEG.

It is assumed that fractures of the leg constitute about sixteen per cent. of all fractures. They occur predominantly between the ages of thirty and sixty, but are rare in childhood.

Some of our former views on fractures of the leg were also radically shaken by the Röntgen rays, and most of our knowledge had to be greatly modified. As in fractures of the lower end of the radius, fissures

and fractures that formerly were entirely unknown were found to be of frequent occurrence. Fissures as well as comminuted infractions had been overlooked in the pre-Röntgen era, because they showed no tendency to displacement. Another essential point revealed by the Röntgen rays is that in many instances the injury itself, and particularly the extent of the displacement, was much more serious than was to be expected from ordinary means of examination or by judging from the degree of the deformity.

They are classified best as *epiphyseal separation*, *simultaneous fracture of the tibia and fibula*, and *fracture of either tibia or fibula individually*.

Epiphyseal separation is observed in individuals under twenty. The etiology, signs, and treatment of this injury fall under the same considerations as those of the fractures of the same type, so that a separate description seems unnecessary.

Separation of the tubercle of the tibia, sometimes occurring in children, is treated on the same principles as fracture of the patella, for which, moreover, it is, as a rule, mistaken.

Simultaneous fractures of the tibia and fibula are subdivided into fractures of the upper and middle portions and into fracture of the lower end.

Simultaneous fractures of the tibia and fibula at their upper and middle portions are generally produced by direct violence (passage of a wagon-wheel, falling of a heavy weight, kick of a horse). The predilection is for the middle third, while the upper portion is but rarely involved. It is less frequent in children than fracture of the femur.

If produced by indirect violence (fall from a high

point, misstep on slippery ground), the fracture of the tibia is always below that of the fibula, the tibia being broken first and the fibula then giving way higher up.

The line of fracture is generally oblique or spiral, the transverse variety being found but exceptionally. Indentation is a frequent occurrence.

Compound fractures are extremely common in this sphere, a fact well explained by the situation of the anterior tibial surface directly underneath the integument.

The *signs* are always well marked, a circumstance also explainable by the superficial situation of the tibia, whereby sideward displacement is made distinctly perceptible. There is also outward rotation of the limb and an angular protrusion of the crest of the tibia. The fibular fragments appear less conspicuous, since their protection by the peroneal muscles makes their palpation somewhat more difficult. But the shortening and the marked abnormal mobility prove the simultaneous fracture of the fibula beyond a doubt.

In the far less serious event of indentation, displacement, abnormal mobility, and crepitus are naturally absent, the signs being limited to intense local pain and loss of function.

The *treatment* consists in reposition by extension on the foot, which is held rectangularly, and by counterextension on the knee. Under this manipulation shortening disappears at once. Protrusion of the upper fragment is counteracted by elevating the heel in order to draw the lower fragment downward and forward. Still more effectual is counterpressure exercised by a weight, which should be attached to the area of the upper fragment. If the inner margin of the

patella is in line with the inner side of the ball of the great toe, the position is correct.

The best chances for keeping the fragments in proper apposition are offered by the plaster-of-Paris

A. B.

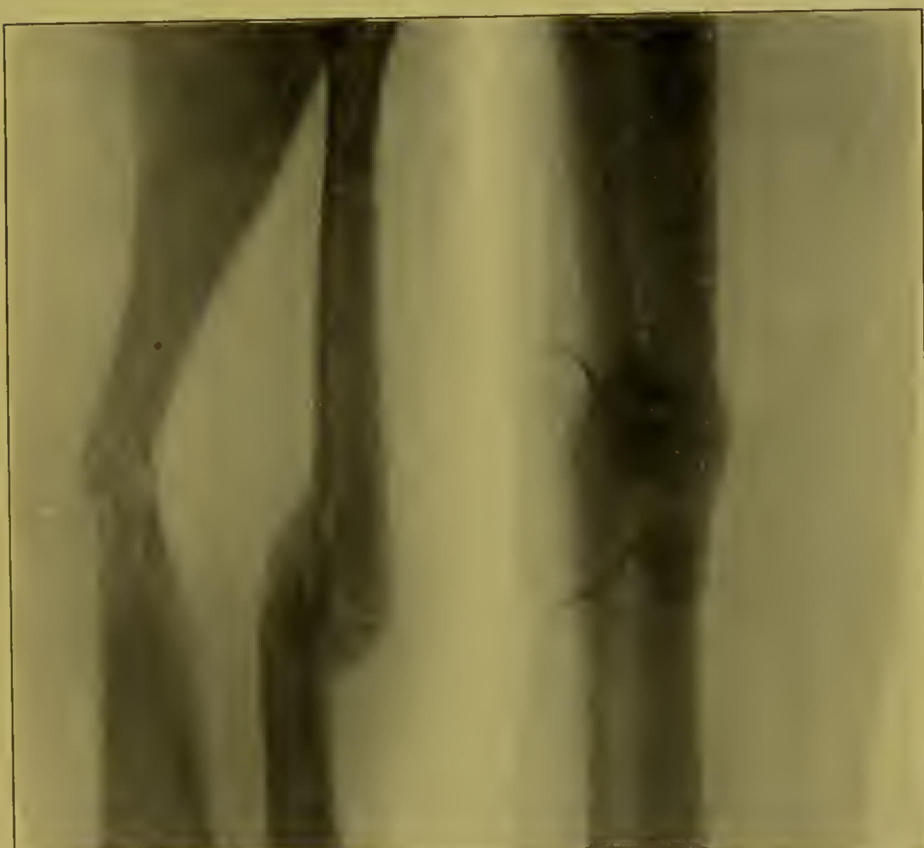

Fig. 127.—Fracture of diaphysis of tibia and fibula. A, Pseudarthrosis relieved by wiring; wire of tibial fragments still *in situ;* B, non union, fragments wired three months after the injury.

dressing, which is applied while extension, counterextension, and counterpressure are exercised. (Compare Figs. 5, 116.) If padding is well done, there is no fear of the supervention of pressure gangrene. If the case can not be kept under daily control, and especially if

the patients be unintelligent, or if there be much tension and swelling, splints are preferable.

The *ambulatory dressing* (compare Fig. 6), in which the patient can walk about on crutches, can be applied after from four to seven days. The modus operandi

Fig. 128. — Supramalleolar fracture in a man fifty-eight years of age. Although displacement was apparently slight, filling-up of the interosseal space causes great functional disturbance (two years after the injury).

consists in applying, after the skin is well oiled, a solid plaster-of-Paris dressing from the metatarsus up to the lower third of the thigh. The support is furnished by the femur and its condyles. The sole of the dressing is fortified by inlaying with strips of tin, zinc, or wood.

It is amazing how many fractures of the leg, even in these days, heal with more or less deformity. Pseudarthrosis (Fig. 127, A) and non-union (Fig. 127, B) are also frequent occurrences. In the latter event osteotomy must be performed. In children, in whom the injury is often the result of being run over, the com-

Fig. 129.—Supramalleolar fracture combined with infraction of fibula in a woman seventy years of age, showing moderate displacement. Function perfect (four weeks after the injury).

pound variety is prevalent. Still, the most unfavorable cases have an astonishing tendency to heal under careful observation of aseptic principles. (See p. 52.)

Simultaneous fractures of the lower end of the tibia and fibula are either supramalleolar or malleolar.

(*a*) *Supramalleolar fracture* (Figs. 128, 129, and

130) of the bones of the leg is produced by direct as well as by indirect violence, the lines of fracture running into the ankle-joint in the majority of cases. This type is analogous to the supracondylar fracture of the femur and humerus, and is generally of a severe character.

Fig. 130.—Supramalleolar fracture in a man forty-two years of age, showing considerable displacement. The interosseous space is filled up with displaced fragments, which cause great functional disturbance (four months after the injury).

The *signs* are very well marked, displacement being the most prominent one.

The *treatment* consists in reposition and immobilization by wire splints, molded after the shape of the foot and leg, or by a well-padded plaster-of-Paris splint.

Reposition is much more difficult then than that of the well-known simple malleolar fracture. Anesthesia can but rarely be dispensed with. If a plaster-of-Paris dressing is applied, thorough revision must be performed at least once a week. Massage treatment should be commenced after two weeks. Restoration to perfect functional ability may not take place for a year. If the interosseous space is free, no functional disturbances may be present even in cases of deformed

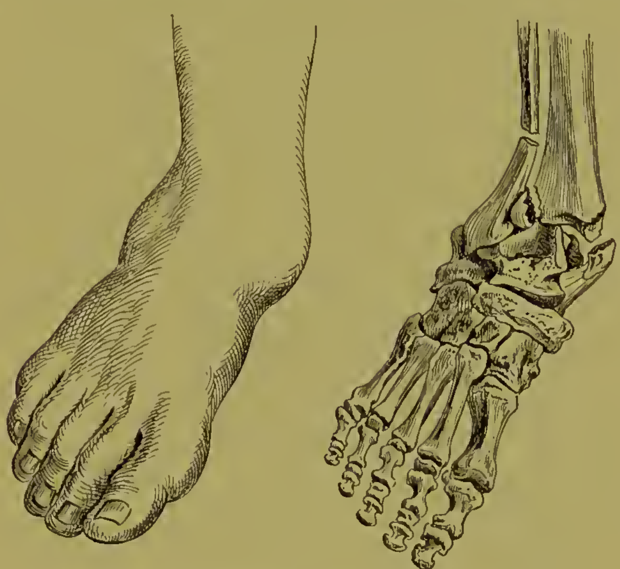

Fig. 131.—Malleolar fracture.—(After Hoffa).

union. (Fig. 129.) But if the interosseous space is filled up with displaced fragments and abundant callus (Fig. 130), osteotomy will be indicated.

(*b*) *Malleolar fracture*, usually called Pott's fracture (Fig. 131), is generally caused by the body being bent down and outward while the foot is kept fixed.

This type is analogous to the fracture of the lower end of the radius, the strong ligamentum carpi volare profundum of which never breaks. The ligamentous

connection of the tibia with the fibula is so strong that its fracture is generally followed by the break of its fellow. In the corresponding typical fracture of the radius the ulna does not always follow the example of its fellow, but, as emphasized in the section

Fig. 132.—Malleolar fracture in a woman thirty-six years of age, showing a long oblique splinter separated from the external malleolus and a small fragment detached from the internal malleolus (ten days after the injury).

on Radial Fracture (p. 153), in many instances it becomes infracted.

Among the *signs* the most prominent one is a very well-marked displacement, the direction of which is generally sidewise. It should be borne in mind that if the fracture extends over only a small portion of the malleoli, the function of the leg may be so little dis-

turbed that the patient is able to walk considerable distances; and if the examination be not thorough, contusion or distortion may be erroneously diagnosticated—as, for instance, in the case illustrated by figure 132. (Also compare remarks on Fracture of the External Malleolus, p. 224.)

The extravasation being sometimes considerable, it can be understood that in many instances but little displacement is shown. In such cases palpation always reveals the presence of the fracture. Crepitus is also seldom absent. Taking into consideration its close relation to the ankle-joint, it is easily understood that this injury represents a severe fracture type. In fact, there is a great tendency to deformity as well as to the development of a severe form of arthritis.

It has been the author's experience that, especially in childhood, inflammatory processes of the ankle-joint were not infrequently mistaken for old malleolar fractures. This may appear strange at first sight; but in view of the fact that tuberculosis in this region often develops after slight injuries, it is not unnatural that the swelling caused by the tubercular process should be mistaken for a deformity following fracture.

In osteomyelitis a preceding subcutaneous trauma is also often reported. The intense pain, the edema, the fever, and the general debility, as a rule, so significant for osteomyelitis, may be sometimes so little marked that differentiation becomes difficult. Figure 142 illustrates this possibility. In this case an anemic girl, eleven years of age, sustained an apparently slight injury by falling on the street. There was moderate pain and slight swelling around the ankle-joint, which was regarded as a sprain until the swelling gradually

extended. It was then assumed that there had been a fracture, the displaced fragments of which had caused the swelling, the deformity, and the disturbance of function. A skiagram, taken five weeks after the injury, revealed the presence of an osteomyelitic focus at the lower end of the tibia, and no signs of a preceding injury to the bone. The swelling not permitting thorough palpation of the malleoli, the error appears very pardonable. (As to etiology and differentiation, compare case illustrated by Fig. 37.)

The focus was exposed under the guidance of the skiagram and was extirpated. The ease and the security with which these operative procedures can be carried out under the control of the rays should be emphasized. Formerly it was deemed advisable to chisel up the bone in its whole length in order to be sure that every possible focus was really reached. Now the skiagram dictates even the length of the incision necessary for a thorough removal.

The *dislocations* in the ankle-joint, which are usually either backward or forward, show such characteristic signs that differentiation should not meet with any difficulty. The rare type of subastragalar dislocation, however, which is either inward or outward, may be confounded with a fracture, as long as the Röntgen rays are not consulted.

The *treatment* consists in exact reposition, which is effected while adduction is exercised, the fibula being forcibly pressed against the tibia. To accomplish this well, anesthesia is required in the majority of cases.

Immobilization is kept up by a plaster-of-Paris dressing, which is applied while the foot is adducted to the rectangular position; that is, in a direction such as the

planta pedis would normally assume in walking. Whenever the plaster-of-Paris dressing can not be used, the Volkmann splint or the removable plaster-of-Paris splint is to be employed. Massage treatment should be started two weeks after the injury. Whenever there is such doubt as to the significance of the

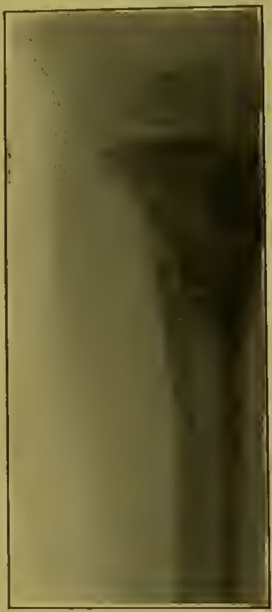

Fig. 133.—Isolated fracture of tibia at its upper end in a girl three years of age (three weeks after the injury).

Fig. 134.—Fracture of the shaft of the tibia in a woman twenty-five years of age, sustained at the age of five, after an operation for necrosis of the tibia.

injury of the malleolar region that the question can not be settled instantly by a Röntgen apparatus, the case should be treated as one of severe fracture.

Union is generally perfect in four weeks. Stiffness of the ankle-joint and swelling of the soft tissues continue often after perfect consolidation. If apposition was correct, these conditions will yield to forcible motion of the joint, local baths, and massage. In

the case of union in a perverse position, which is a frequent result, osteotomy is always indicated.

Isolated Fracture of the Tibia.—Isolated frac-

Fig. 135.—Same case as figure 134, showing enormous development of the greatly deflected fibula and the arrest of growth in the tibia. A new movable joint, containing normal synovial fluid and showing well-developed synovial membranes, had formed.

ture of the tibia may take place at its upper or lower end, or it may take place through the shaft.

(*a*) *Isolated fracture through the upper end of the tibia* is caused by direct as well as by indirect violence.

Injuries of this kind are rare. (Fig. 133.) They are produced by compression. This fracture may be due to gunshot or to a vertical fall on the foot (fall from a bicycle)—other injuries generally producing simultaneous fracture of the fibula. If the line of fracture is transverse, there is little displacement, the fibula acting as a kind of a side-splint to retain the

Fig. 136.—Comminuted fracture of the tibia caused by gunshot from fifty yards' distance (skiagraphed one hour after the injury).

fragments in apposition; but there is local pain, ecchymosis, and a more or less marked irregularity on the anterior tibial surface. If the line of fracture is oblique, there is more or less lateral deflection.

Without the aid of the Röntgen rays, however, an exact diagnosis is often impossible.

In fracture of the tibia due to necrosis the growth of the bone may be arrested, as shown in figures 134

and 135, where the fibula had practically assumed the function of the tibia.

The *treatment*, if there is any displacement, consists in reposition. Otherwise the treatment is identical

Fig. 137.—Indications of oblique fracture of the left tibia failing to be represented by the Röntgen rays in the dorsal position.

with that for the simultaneous fracture of the tibia and fibula.

(*b*) *Isolated fracture of the tibia through its shaft at about its middle* may be due to direct as well as to indirect violence, such as a kick, a knock, a fall, or a

gunshot. (Fig. 136.) In children infraction of the shaft is often the result of a moderate degree of violence. (Fig. 138.)

The fracture line is sometimes transverse; in the majority of cases it is oblique, and if there be but little displacement, the diagnosis of the fracture may

Fig. 138.—Infraction of tibia in a boy four years of age (three hours after injury).

be difficult without the aid of the Röntgen rays. (Compare the history of the case illustrated by Fig. 139, *a* and *b*, and described in the section on Errors in Skiagraphy.)

The *treatment* is the same as that for isolated fracture through the upper end of the tibia.

(*c*) *Isolated fracture of the lower end of the tibia*

(isolated supramalleolar fracture) has the same etiology as the simultaneous fracture type described previously, with the exception that the force producing it is usually less violent. In childhood infraction is observed sometimes as illustrated by figure 138.

The *signs* are not always well marked. There being

A. B.

Fig. 139.—Fracture of the tibia. Same case as figure 137. A. Oblique type, in a boy four years of age (twelve hours after the injury). B. Union nearly perfect (four weeks after the injury).

no deflection present, they are limited to one unreliable symptom only: namely, the local pain and tenderness, which could just as well be due to a simple fissure or a distortion. (Fig. 140.) The Röntgen rays, of course, will never fail to elucidate the true character of the injury.

The *treatment* falls under the same consideration

as pertains to the simultaneous fracture type. (Page 206.)

Fig. 140.—Spiral fracture of the lower third of the tibia in a boy of three years (twenty-four hours after the injury). (Note relations of the cartilaginous epiphyses in the knee-joint.)

As long as any doubt as to the character of the injury exists, it should be treated as a fracture. If

reposition has been imperfect, shortening of the leg and considerable thickening of the ankle-joint may result. Atrophy of the muscles of the leg, varus- or valgus-position, etc., may prevent the patient from walking normally. If, in case of considerable dis-

Fig. 141.—Fracture of the lower end of the tibia in a man fifty-two years of age, showing considerable backward displacement. Great functional disturbance (one year after the injury).

placement, reposition has been omitted, the tibial fragments may be shifted away from their natural relations, particularly in the articulations between tibia and fibula. This condition is illustrated by figure 141, which shows protrusion of the lower tibial fragment to an enormous extent.

It goes without saying that in such an event the function of the ankle-joint is greatly impaired. When consolidation is not perfect (three to five weeks after the injury), there is a chance for redressing the protruding fragment under anesthesia, but later on the only remedy possible is offered by osteotomy.

Epiphyseal separation of the lower end is some-

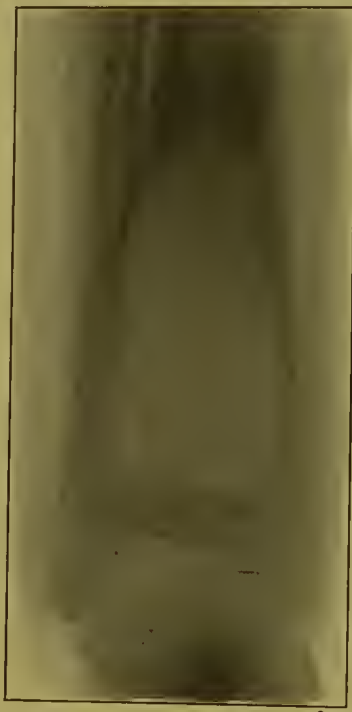

Fig. 142.—Osteomyelitic focus in the lower end of the tibia, characterized by the translucency of the diseased area.

times caused by traction during labor. In connection with fracture of the fibula, compound separation takes place sometimes in older children. The treatment is the same as that for isolated fibular fracture.

Isolated Fracture of the Fibula (Fig. 143, A and B).—The isolated fracture of the fibula generally occurs at the lower third.

The signs as well as the treatment fall under the same considerations as those of the malleolar fracture.

The fibula may also fracture at any other point, but such occurrence is extremely rare. The signs of the

A. B.

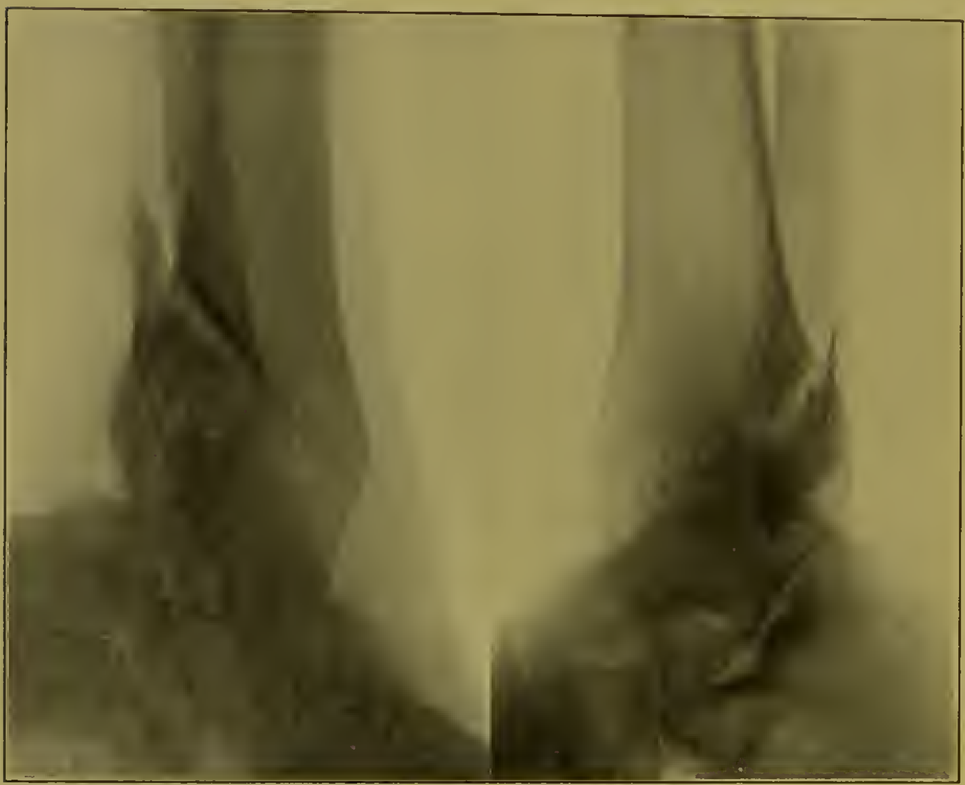

Fig. 143.—A. Isolated fracture of the fibula in a man twenty-nine years of age (one day after the injury). B. Isolated fracture of the fibula, causing moderate functional disturbance, in a man forty-two years of age (three weeks after the injury).

latter type are but little marked, the only important one being represented by local pain.

The cause of the fracture of the fibula at its lower end, which is also called *fracture of the external malleolus*, is the same as that of distortion. The outer margin of the astragalus pressing against the external malleolus, while the foot is bent in forced supination, it

is natural that the malleolus yields above the margin of the astragalus, since the very strong calcaneofibular ligament generally resists the force. The comparison with the mechanism of the fracture of the lower end of the radius is also obvious.

Some patients are able, after having sustained a fracture of the external malleolus, to walk, and even to work, so that the erroneous diagnosis—distortion—is often made. The author is convinced that he has committed this error himself before he had a chance to avail himself of the advantages of the Röntgen rays.

If such cases are consequently treated as distortions by the application of ointments, fomentations, etc., enormous callus formation of the external malleolus and varus-position may be the result. Naturally, the relation of the external malleolus to the astragalus is influenced by the faulty position. The external margin of the foot exclusively being utilized while walking, it is natural that the metatarsal bones are also shifted sideward, and finally even the knee will participate in the faulty position.

The *treatment* consists in simple immobilization (plaster-of-Paris). The tibia acting as a side splint, union becomes perfect under almost any immobilizing treatment.

The rule that osteotomy must be resorted to in case the function of the extremity is disturbed applies to all the various types of fractures of the leg in which union has taken place in a *faulty* position, provided the proper time for bloodless redressement has elapsed. The modus operandi is practically the same as that described for osteotomy of the femur—that is, chisel-

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ing off of protruding or intervening fragments, or severing the displaced fragments entirely by means of a chisel or the Gigli wire saw. (Compare p. 189.)

Pseudarthrosis requires osteotomy much more frequently, especially in children, in whom the fractured ends have a tendency to become thin and atrophic, thus reducing the extent of their surface, which is a most unfavorable item in the question of agglutination. Such patients are unable to work without an immobilizing apparatus or a prosthesis. Wherever the surfaces are too small for perfect approximation, the bone-fragments should be freshened laterally and united by strong silver wire. (See Fig. 13 *c*.)

It is of the greatest importance that no periosteum should be sacrificed during the operation.

In the event of extensive loss of substance of the tibia, the upper tibial fragment may be united with the lower portion of the fibula after the latter has been trimmed proportionally.

FOOT.

Fracture of the foot concerns either the tarsal or the metatarsal bones or the phalanges.

Fractures of the tarsal bones are always caused by direct violence (passing of a carriage-wheel (Fig. 144), falling of a heavy weight upon the tarsus). There is often extensive destruction of the soft tissues present at the same time. The astragalus and calcaneum are the tarsal bones most frequently involved in these fractures.

Fracture of the astragalus (Fig. 145) is generally caused by a fall, its neck representing the seat of pre-

Fig. 144.—Fracture of tarsal bones, caused by a heavy truck, followed by gangrene of foot, in a boy four years of age. Line of demarcation above the malleoli ecchymotic, but healthy integument appearing prominent above the gangrenous area; skin peeling off from the gangrenous dorsum (ten days after the injury).

Fig. 145.—Compression fracture of astragalus in a twenty-eight-year-old laborer who was run over (four weeks after the injury).

dilection. It is often associated with other severe injuries of the ankle-joint. The atragalus is a peculiar bone inasmuch as it articulates with four different bones and shows no point of insertion for any tendon. Its fracture may concern the *body* as well as the *neck* of the capitulum.

The *signs* consist in the presence of local pain and tenderness, crepitus, and loss of function. In the rare event of displacement the possibility of dislocation may be thought of. The considerations would be then

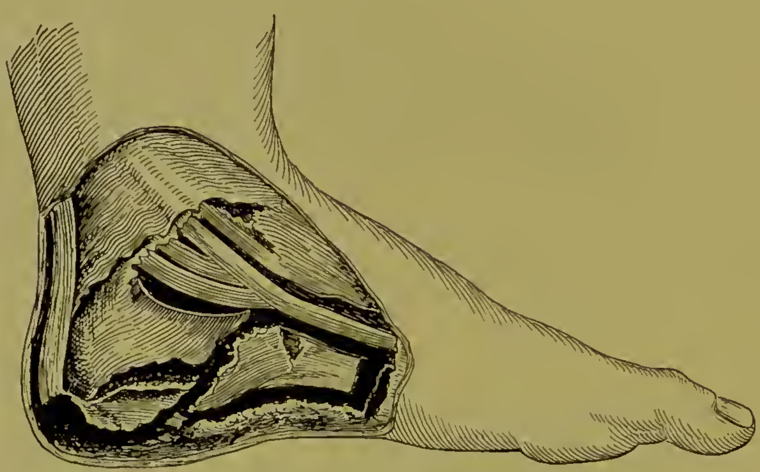

Fig. 146.—Fracture of the calcaneum.

that the malleoli appear to be intact, that there is considerable shortening of the extremity, and that the characteristic contours of the astragalus can be well palpated. Fracture of the astragalus often remains unrecognized and is treated for malleolar fracture or distortion of the ankle-joint. The Röntgen rays, of course, will always disclose the true condition.

The *treatment* consists in reposition in case of displacement, and this is possible sometimes only after division of the tendo Achillis. If there be but little

swelling, immobilization is accomplished by a plaster-of-Paris dressing. Otherwise, especially in the event of synovitis, wire splints in connection with the application of Burow's solution are indicated. (See p. 67.)

Fig. 147.—Non-reduced fracture of the calcaneum, showing considerable sideward displacement, thus resembling dislocation, in a man thirty-eight years of age. Enormous swelling (two weeks after the injury).

Fracture of the calcaneum (Fig. 146) is caused either by direct violence (fall from a high point, passing of a cart- or carriage-wheel) or by indirect violence (sudden contraction of the tendo Achillis). It predominates in

masons, roofers, miners, and workmen on elevated railroads. It concerns either the *body* or the *processes* of the bone.

The *signs* consist in ecchymosis, local pain, displacement, crepitus, and loss of function. The arch of the foot sinks down and the foot appears flat. Sometimes the swelling following the injury is so consider-

Fig. 148.—Oblique fracture of first metatarsus in a rachitic girl of twelve years; healed without deformity (five weeks after the injury).

able as to prevent exact palpation; and as a consequence distortion or malleolar fracture may be erroneously supposed to exist.

The prognosis as to function is always doubtful.

The *treatment* consists in reposition and immobilization. The first requirement sometimes can not be

fulfilled, apposition of the fragments being possible only by bone suture or ivory pegs. Ordinarily, the displacement can be overcome by resting the leg upon a double inclined plane. In case of excessive callus formation resection of the exuberant masses is indicated. If either the calcaneum or astragalus is crushed, amputation should be performed without delay.

Fractures of the scaphoid, cuneiform, and cuboid bones fall under the same considerations as those of the metatarsal bones. In all these fractures the arch of the foot sinks down, causing talipes-position.

Fractures of the metatarsal bones (Fig. 148) **and the phalanges** are always produced by direct violence (falling of a heavy weight, passing of a wagon-wheel, the latter being an especially frequent cause in children). Such fractures are either isolated or simultaneous, sometimes all the bones being fractured at the same time. Usually these injuries are associated with lesions of the soft tissues. Their superficial location makes recognition of the character of these injuries easy, as a rule.

Fracture of a metatarsal bone, especially the second or third, is frequently observed in the army, as a consequence of overburdening the marching soldier. In the pre-Röntgenian era this much dreaded condition, known as "foot edema," was regarded as dependent upon a pathologic change in the soft tissues.

The *treatment* consists in immobilization by a small plaster-of-Paris dressing after reposition is done. Union generally becomes perfect in three weeks.

In compound fractures the wire splint should be used in connection with antiseptic lotions. (See p. 67.)

Later on, the fenestrated plaster-of-Paris dressing is to be employed. (Fig. 5.)

If the bones are crushed, amputation should not be delayed.

FRACTURES OF THE BONES OF THE TRUNK.

Fractures of the bones of the trunk are divided into those of the thoracic wall (ribs and sternum) and those of the spinal column (body, arch, and the spinous and transverse processes).

FRACTURE OF THE RIB.

Fractures of the ribs (Fig. 149), while rare in children, are frequent in adults, and represent fifteen per cent. of all fractures. The injury may be caused by direct as well as by indirect violence. In the first event (blow against the thoracic wall, fall at the margin of the sidewalk, staircase, table, etc.) the fragments are generally driven inward. (Fig. 150.) If caused by a gunshot, the rib is splintered, the intrathoracic organs being generally also involved. A simple transverse fracture may be produced by a bullet fired from so great a distance that its force is considerably diminished when it strikes the rib.

If the fracture is caused by indirect violence (as, for instance, by compression of the thorax), it is often associated with fracture or contusion of the humerus. In rare instances the fracture is produced by muscular contraction, in which event the fragments are generally driven outward.

According to the age of the patient or to the degree of violence, an infraction (Fig. 149) or a true fracture

(Fig. 150) may result. Infractions are much more frequent than fractures. In children the thorax is so elastic that fracture is caused only by a considerable degree of violence.

The **signs** consist in intense local pain and in the crepitus that results if the fragment is pressed downward by the palm of the hand. Manual pressure also increases the painful sensation during the act of inspiration. Deep inspiration and stooping toward the opposite side invariably cause great pain. If the rib

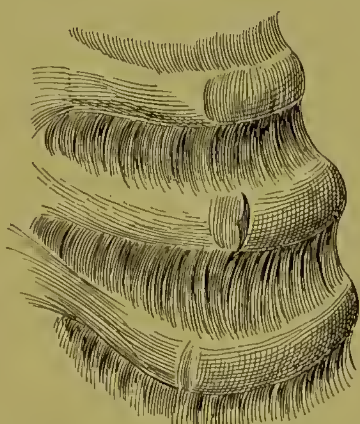

Fig. 149.—Infraction of ribs (no displacement).

is fractured only, displacement generally does not take place, but if several ribs are broken, as shown by figure 150, considerable displacement may result. It is in these cases that the intercostal artery may become injured, so that an aneurysm may develop. Fractures in the vicinity of the vertebræ impair the function of the articulatio costotransversalis and costovertebralis.

In case the lungs are injured, hemoptysis is always, and hemothorax, pneumothorax, and emphysema are sometimes, present. The last-named condition may

extend to the neck and abdomen, and in severe cases it may involve the whole body, the air escaping from the lung into the surrounding connective tissue. The left fourth, fifth, and sixth ribs at their sternal junctions endanger the pericardium and vagus, while the anterior splinter-fractures of the sixth rib may injure the

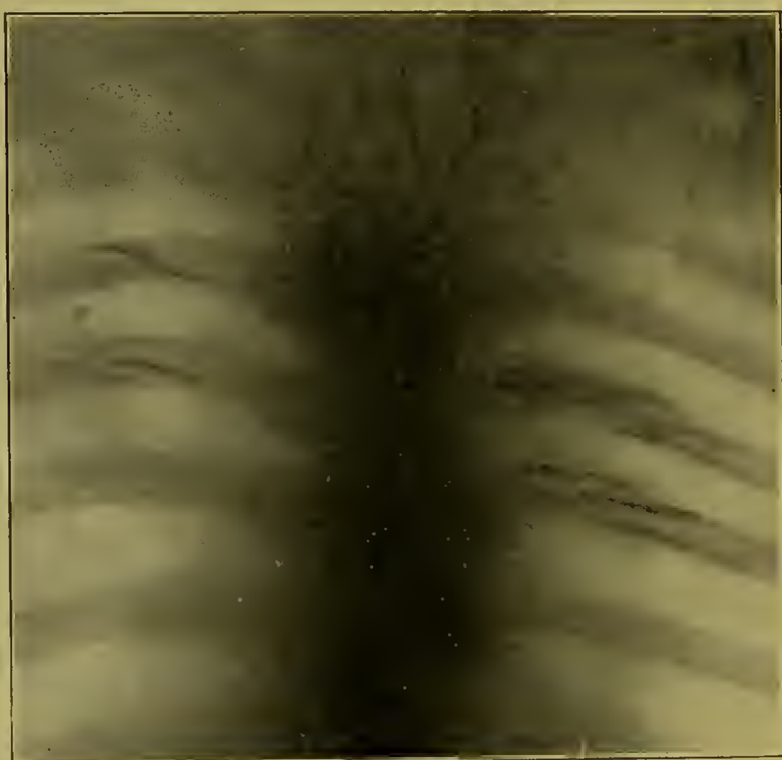

Fig. 150.—Fracture of ribs about their angles, causing kyphosis, in a woman of fifty years. On the left, the fourth rib shows slight, the fifth considerable, displacement. On the right, the fragments of the fifth rib overlap, while the sixth rib shows moderate displacement.

pleural sinus. The right seventh, eighth, and ninth ribs may cause laceration of the liver tissue.

The **treatment** should be mainly directed to immobilization. Taking into account the relation of the ribs to the pleura and lung, it is evident that immobili-

zation should not be expended upon the thoracic wall alone, but must also affect the intrathoracic organs.

The first requisite will be attained by the fixation of the fragments, which is accomplished by a large and broad strip of rubber adhesive plaster or a large piece of moss-board (see Fig. 23) applied during expiration. The second and more important requisite, immobilization of the lungs,—in other words, reduction and diminution of the respiratory movements,—is fulfilled by a liberal administration of opiates.

Pleuritis sicca, one of the most frequent results of simple infraction as well as of true fracture of a rib, is treated after general principles (rest in bed, fomentations, opiates, etc.).

The same views apply in the much rarer event of pneumonia, which, as a rule, is of moderate extent and significance. Sometimes tuberculosis develops after an injury of the pleura or the lungs.

Hemothorax or pneumothorax, if present to a moderate extent, demands aspiration, under the most thorough aseptic precautions. (Compare p. 198.) In most cases, however, it is more rational to expose the pleural sac by the resection of three or more ribs. The same holds good in pyothorax. As to the technic, compare author's description.*

Pericarditis is not infrequently observed after rib-fracture. If a splinter-fragment has pierced the pericardium, injury to the heart may also result. The true character of the trauma can always be elicited by the Röntgen rays. If, for instance, the clinical symptoms are slight, and the rays show no displaced splinters in the direction of the pericardium, medical treatment

*"International Med. Magazine," January, 1897.

alone is in order. Even if a bullet, after having fractured a rib, has entered the pericardium, there may be no need of surgical interference, no severe symptoms being present. An autopsy made by the author on a patient who was shot through the thorax eight years

Fig. 151.—Compound fracture, showing displacement of fifth, sixth, and seventh ribs, in a boy ten years of age (four weeks after the injury).

before his death revealed a bullet embedded in fibrous tissue in the pericardial sac, where it had never caused any disturbance.

But the evidence of a sharp bone-splinter pointing toward the pericardium indicates the urgent necessity of exposing the pericardial sac after the resection of

the left fourth, fifth, and sixth ribs. They do not necessarily need to be resected in their totality, but may be folded up at their sternal junctions like a bone-flap of the skull. (Fig. 158.)

It goes without saying that in such cases the clinical symptoms are severe according to the anatomic condition.

The signs of an injury to the heart are severe shock (fainting, cyanosis, weak pulse), pulsation in the wound, hemopericardium, and the murmur. If the fourth and fifth ribs are dissected at the mammillary line and folded up at the sternum, the anterior surface of the right and a portion of the left ventricle are exposed. The pericardium must be severed from the pleura. Any wound in the heart must be united with silk (medium size). The left ventricle is best sewed during systole, and the right during diastole.

In compound fractures of a rib (Fig. 151) the packing of the wound with iodoform gauze is indicated. If there be much hemorrhage, the packing must be done tightly and extensively, in the form of a tampon bag.*

If the extent of emphysema is moderate, no interference is required; but if it be extensive, multiple incisions are indicated.

To sum up, it can readily be seen that the prognosis of fracture of the ribs depends entirely upon the degree of participation of the intrathoracic organs. In simple cases union is perfected in from three to four weeks.

Fractures of the costal cartilages occur generally at their junction with the ribs, sometimes also in

* Compare author's "Manual on Surgical Asepsis," W. B. Saunders, Phila., p. 209.

their continuity. The consideration of the etiology, signs, and treatment of this condition is identical with that of fracture of the ribs. It must be considered that in aged people the cartilages become ossified.

FRACTURE OF THE STERNUM.

Fracture of the sternum (Fig. 152) is rare (less than one per cent. of all fractures). It is generally caused

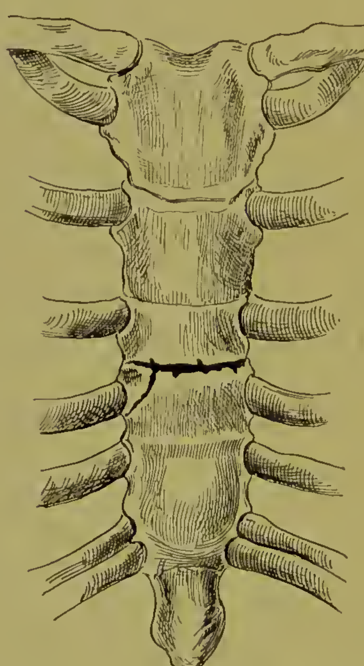

Fig. 152.—Fracture of the sternum.

by direct violence (heavy weight falling upon the chest, gunshot wound, etc.). The line of fracture is nearly always transverse. It is but exceptional that it is caused by indirect violence (muscular contraction, sudden bending of the trunk, the chin being pressed against the sternum).

If caused by a gunshot wound, the seat of the frac-

ture may be at any portion of the sternum. Otherwise it is generally at the junction of the manubrium with the corpus.

The **signs** are local circumscribed pain, more or less displacement and crepitus, cough, and sometimes hemoptysis and dyspnea.

The **prognosis** is favorable except in cases in which there is injury done to the mediastinum.

The **treatment** consists in reposition of the fragments. This is accomplished by putting the patient into a reclined position by placing a large pillow under him, so that the receding fragment protrudes. The head should be bent far backward at the same time. If this procedure does not prove to be efficient, extension with Glisson's cradle is advisable.

FRACTURE OF THE SPINAL COLUMN.

Fractures of the spinal column (Figs. 153, 154) are rare (less than one per cent.), and are subdivided into fractures of the vertebral body, the arch, and the spinous and transverse processes.

Fracture of the vertebral bodies occurs generally in the dorsal and lumbar portions. The place of predilection is between the twelfth dorsal and the first lumbar, and at the fifth or sixth cervical vertebra. It is generally caused by indirect violence (heavy weight falling upon head or shoulder, fall from horse or bicycle). Direct violence produces it but exceptionally.

The direction of the fracture-line may be either oblique, transverse, or longitudinal. The first variety is the most frequent, the last-named the rarest.

Infractions or fissures are also observed, but they are seldom diagnosticated on the living patient. Sometimes more than one vertebra is concerned.

The most important *sign* is the traumatic kyphosis, produced by displacement of the spinous processes, whereby a prominence is caused. Naturally, there is always circumscribed pain. Crepitus and abnormal mobility are generally absent.

In case of a crushing of the bone the spinal cord

Fig. 153.—Position of trunk in fracture of the spinal column.

hardly ever escapes injury, the latter generally being of the nature of a severe contusion. Lighter injuries, such as commotion or compression, are of exceptional occurrence.

In the event of medullary contusion there are well-marked signs of motor and sensory disturbance: viz., paralysis of both legs, of rectum and bladder, local anesthesia of the anal and perineal regions, and sometimes priapism. In severe cases dyspnea and high

temperature may complete the symptom-group of this grave condition.

While in commotion and compression (caused in some instances by a blood extravasation) there is only slight paresis, which disappears in a few days, in contusion the paralytic symptoms remain unchanged. Spinal myelitis develops, with an ascending tendency, the paralysis progressing in the centripetal direction.

The paretic bladder breeds cystitis and pyelonephritis, and the anesthesia of the paralyzed portions tends to decubitus on the prominent bone-portions of the pelvis and the lower extremities, so that there are present all the conditions for the development of pyemia.

The higher up the fracture takes place, the less favorable is the prognosis. Importance should be attached also to the proximity of the injury to the vital organs.

If in fracture of the first and second cervical vertebræ the spine is compressed on account of much displacement, death is almost instantaneous. If the degree of displacement is very slight, the patient may live for a short while.

In view of the fact that the brachial plexus is composed of the fifth, sixth, seventh, and eighth cervical nerves, as well as of the first dorsal nerve, it will be understood why paralysis of the upper extremities as well as of the abdominal and intercostal muscles is present in fracture above the third dorsal vertebra; also why the character of the respiration is distinctly diaphragmatic, and why it is the diaphragm only, besides a few cervical muscles, that keeps up the respiratory function.

If the phrenic nerve, which branches off between

the third and fourth cervical vertebræ, is compressed in this region, its paralysis will be the consequence, and death will follow almost instantly.

Fig. 154.—Fracture of dorsal vertebra, causing displacement and contusion.

In fracture between the third dorsal and the third lumbar vertebra the spine is injured below the

brachial plexus. Consequently, the function of the arm remains intact, while the functions of the bladder, the rectum, and the lower extremity are suspended, first retention, and later on incontinence, of urine and feces setting in.

If the line of fracture is situated higher up, the abdominal muscles may also become paralyzed. Then tympanites will be produced, which pushes the diaphragm upward so that respiration is greatly interfered with. Some of the intercostal muscles may also be paralyzed, so that the respiratory difficulty is so much more increased.

There may also be the chain of symptoms of irritation, such as hyperesthesia, neuralgia, and spasms. The reflexes are increased if the compression is considerable, while they may be unaltered if it is slight. The vasomotor sphere may react by an enormous elevation of temperature if the lower cervical region is involved. Continuous erection and frequent ejaculations of sperma may also persist for days.

The *treatment* consists in reposition of the fragments. Sometimes this can be accomplished by manual force applied after the induction of profound anesthesia. This can especially be done in the lower dorsal and in the lumbar portions. The fragments are drawn apart by placing the patient in Glisson's cradle, counterextension being accomplished by elevating the bed. Later on, a plaster-of-Paris corset is applied while forcible weight-extension is kept up.

If reposition is impracticable, distraction or the forcible separation of the fragments must be resorted to.

In the *treatment* great stress has to be laid on very

careful control and nursing. Frequent change of position, while necessary, must be done under great precautions, as it must be remembered that even a light torsion of the injured spine may cause instant death. The patient rests best on a water-pillow or, preferably, on a water-bed.

Decubitus must be prevented by exercising the most minute cleanliness and by placing the patient upon rubber water-bags. Frequent change of position is also required.

Decomposition of the urine must be counteracted by frequent catheterization, followed by irrigation with a weak solution of bichlorid of mercury (1 : 25,000) and injection of a five per cent. emulsion of iodoform in glycerin.

With the aid of the Röntgen rays the type of the fracture and the size and number of the splinters and their location can be so well represented that the indications for the mode of treatment are set forth clearly. If there is only slight angular displacement, reduction can nearly always be accomplished. But in the event of intraspinal hemorrhage and when bone-fragments, driven into the canal, press upon the cord, operative interference is required.

Under the application of the Röntgen rays the results of operation, which formerly had been confined to exploration, became much more encouraging. The field of operation being outlined by the skiagraph, the modus operandi could be determined before operation. While at one time it was deemed advisable to expose a large portion of the spinal column in order to ascertain that every possible injury had really been reached, now all the operative procedures can

be carried out under the indication of the rays with ease and security, even the length of the incision necessary for the removal of bone-splinters being shown by the skiagraph.

It is surprising that surgeons who find it most natural to relieve by immediate operation bone-pressure caused by a depressed fracture of the skull should hesitate to perform the similar operations upon the spinal column. Nothing, indeed, is more natural than reduction or removal of a fragment pressing upon the spinal cord. Blood-clots can then be evacuated from the cord; and its membranes, and even wounds of the nerve-tissue, may be united. It is hardly necessary to add that such procedures must be carried out under the most stringent aseptic precautions. (Compare p. 52.)

The best method of exposing the spinal canal (trephining of the spinal canal, or laminectomy) is by the formation of a lateral flap. This is done by making an incision about seven inches long over the arches down to the periosteum and by reflecting the soft tissues to the bases of the spinous processes, which are then divided with cutting bone-forceps. The processes may be lifted up in the flap, like a bone-flap in the skull. (Fig. 160.) The dissection is continued to the other side until the exposure of the fractured area is complete. Now the depressed bone may be lifted or removed, a hematoma may be evacuated, and lacerated nerves may be united. If the bone-flap is reinserted now, union by first intention can be expected, the remaining bone-gap being filled up with thick fibrous tissue.

But if suppuration is present, the principles of open wound treatment should be kept up.*

In case of excessive callus, pressing upon the cord, or of faulty union, laminectomy is also indicated, even at a late period. Sometimes in such cases occlusion of the spinal canal, caused by adhesions of the membranes, is observed. It goes without saying that they must be thoroughly freed.

In view of the soft, spongy consistence of the vertebral bodies, it is evident that long-continued immobilization—at least three months—is necessary for thorough consolidation. If the patient is allowed to get up too early, compression will be increased by the weight of the body, and kyphosis will be a natural consequence.

In severe cases the treatment may be continued for a whole year. Massage treatment should be commenced after three months; later on, faradization is in order.

Fractures of the arch are rare, and occur more frequently in the lower than in the upper portion of the vertebral column. They are caused by indirect violence (fall or blow on the long spinous process) the effect of which is transferred to the arch.

Among the *signs* the predominant one is the downward displacement of the spinous process of the vertebra involved. Otherwise the signs as well as the treatment of this type require much the same consideration as those of the fracture of the vertebral body.

Fracture of the spinous and transverse processes is extremely rare.

* Compare author's essay on "Laminectomy," "American Medico-Surgical Bulletin," Feb. 1, 1894.

Fractures of the spinous processes are caused by direct violence (blow or fall), and prevail at the lower dorsal and the lumbar portions of the vertebral column.

The *signs* are well marked, the predominant one being abnormal mobility of the fragment.

Fractures of the transverse processes are still rarer, and their recognition is extremely difficult on account of the thick muscular layer protecting them.

The *treatment* of this fracture type is very simple. Patients should assume the dorsal decubitus for two weeks, and are then provided with a plaster-of-Paris corset for another few weeks.

A good skiagraph will show a fissure as well as an infraction at any part of the spinal column. In reproducing it in print, however, much of the delicacy of the representation becomes lost, and for that reason the author has preferred not to offer any of his skiagraphic illustrations of this fracture type.

FRACTURES OF THE SKULL.

Fractures of the skull are comparatively rare (1.3 per cent. of all fractures). They deserve special consideration for the reason that their course can seldom be foretold with certainty, extensive penetrating injuries sometimes healing with little reaction and no ill consequence, while comparatively small lesions of apparent insignificance are liable to be followed by fatal meningitis. They concern the vertex or the base of the skull or the bones of the face.

Fractures of the skull are uncommon in *children* on account of the thin and elastic structure of the bones,

which makes them yield to direct violence. This explains why fissures and fractures of the tabula vitrea are so extremely uncommon in childhood. The bones being united by soft sutures and the dura mater being firmly adherent to the infantile cranium, it follows that an injury of the skull will be, with few exceptions, combined with a laceration of the intracranial tissues; at least, of the dura mater. Sometimes the arteria meningea media is found ruptured. Such cases require very careful observation and judgment, since the early symptoms of meningitis or encephalitis may be veiled.

The treatment consists mainly in rigid asepsis. In hernia cerebri caused by compound fracture of the skull transplantation of bone-tissue is indicated. In fracture of the skull in older children, in whom the bones are consolidated, the conditions are the same as in adults.

FRACTURES OF THE VERTEX

represent the great majority of fractures of the skull, and are nearly always caused by direct violence (fall or blow on the head, weapon, gunshot). Indirect violence, the force inflicted radiating, causes it but rarely. (An illustration of the insignificance of indirect violence is afforded by the case of President Lincoln, in which the bullet, after having pierced the left side of the occiput, went to the cranial base below the right anterior lobe. The autopsy revealed a fracture in the roof of the right orbit, which had not been touched by the bullet.)

There may be a simple fissure in the skull, as well as comminuted and compound fractures.

A remarkable feature of fractures of the vertex is the much greater extent of the fracture in the internal

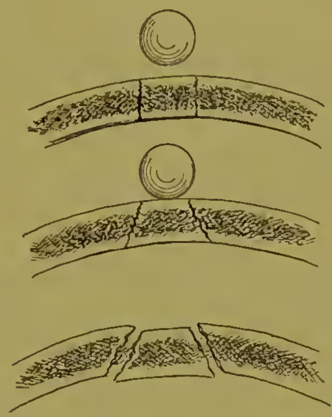

Fig. 155.—Schematic representation of dissemination of force.

Fig. 156.—Protrusion at the inner table, caused by a blow from a hammer.

table than in the external. This is caused by the force bending the portion involved inward. Thus the outer

convexity and the concavity of the inner surface are replaced by a flatness of that portion, the external table being compressed and the internal table being overstretched. (Fig. 155.) The extent of the fracture naturally is greater in the inner table. When a stick is broken, the separation of the fragments commences at the overstretched side, or convexity,

Fig. 157.—Fracture by gunshot, comminuted type.

not on the compressed concavity. In like manner the greatest extent of fracture in injuries of the vertex is shown upon the concave side.

There are isolated fractures of the external table as well as of the internal. The latter injury occurs sometimes when a force, applied from without, is too weak to compress the external table to such an extent as to

cause its fracture, but still is powerful enough to stretch the molecules of the inner table to such an extent that a fracture must result. (Fig. 156.) On the other hand, it may happen that a force (gunshot) inflicted from within is strong enough to fracture the inner, but too weak to permit of its fracturing the outer, table.

Fissures may be limited to the external table, and

Fig. 158.—Fracture of the orbit caused by a revolver bullet, which, after having perforated the left orbit, was arrested at the right sphenoid process.

may represent but a small crack; or they may show an irregular radiating fracture-line (stellate), the branches of which separate widely.

Fractures are generally of the comminuted character, their fragments generally being separated from each other entirely. They may also show an irregular radiating fracture-line (splintered stellate type). The

inner table is always injured to a greater extent than the outer in such cases.

There is often a considerable depression of the splintered area, some of the splinters projecting toward the interior of the skull. Necessarily, the brain must in such cases be more or less injured. If caused by gunshot (Figs. 157 and 158), there may be considerable loss of substance. Usually there is a small round defect at the outer table, comminution at the inner one, and penetration of the splinters into the brain-substance.

The **signs** are local as well as general.

The *local signs* are well marked in open fractures. To ascertain their extent the injured area must be thoroughly exposed. Careful exploration is then made by dilating the wound well and keeping the wound margins far asunder.

Closed fractures, if comminuted, are also easily diagnosticated, especially so if there is depression present; but fissures, which naturally show no displacement, are recognized with difficulty. Their circumscribed blood extravasation below the periosteum and galea is easily confounded with a hematoma of the galea caused by simple contusion. Local pain also represents an unreliable symptom, so that without the aid of the Röntgen rays a positive diagnosis often can not be made.

The *general signs* are more marked than the local. The function of the brain being exercised by some particular circumscribed portions, it is evident that from the particular kind of functional disturbance the impairment of a certain area can be guessed.

The expression of these functional disturbances may

be either paralytic or spasmodic, or both. Destruction of a certain brain-portion means destruction of function —that is, paralysis; while slight injury might only mean irritation, which would find its clinical expression in contractions—spasms.

In other words, if the paralysis extends over a certain group of muscles (circumscribed paralysis; monoplegia), a certain local injury must be suspected. The same statement applies to a combination of paralysis and spasm, while spasms of a certain group of muscles alone (monospasms) point to a lighter injury of the same focus. As in the case of analogous fracture of the spinal column (p. 241), distinction has to be made between *commotion*, *compression*, and *contusion* of the brain.

Cerebral commotion consists in the injury of any small brain particles combined with a slight degree of blood extravasation. It is followed by nausea and vomiting, vasomotor paralysis, which finds its expression in the weak and slow pulse (in several cases, as slow as forty a minute), pallor of the face, coldness of the extremities, superficial respiration, and in the sudden loss of consciousness. The latter symptom may be present for only a few minutes, and would then point to a slight degree of commotion only; but in severer cases unconsciousness may last for two or three days. Then there is also retention of urine, as well as involuntary passage of urine and feces. Among the sequels of this condition diabetes mellitus and diabetes insipidus are sometimes observed—disturbances of tissue-change which would indicate an injury of the fourth ventricle (Claude Bernard).

The most characteristic symptom of cerebral com-

motion is a sudden loss of consciousness, the patient collapsing at the very moment he receives the injury. The clinical picture shows the motionless patient in a soporose condition, the face pale and showing no expression, the staring eyes wide open and the pupils not reacting. If the arm or leg is lifted up, it falls down again without indicating any contraction of the muscles. No irritation of any kind (yelling at the patient or sticking him with a pin) will produce reaction. It is only the weak, superficial, and slow respiration, and the small, slow, and irregular pulse which indicate that life is not yet extinct.

In a very slight degree of commotion, such as is often observed in bicycle accidents, there is loss of consciousness for a few minutes only, followed by slight headache and vertigo, ringing in the ears, and a feeling of general weakness, which passes off in a few hours.

Cerebral compression is always due to extravasation from the arteries, especially the meningea media. It increases gradually, and the amount of intracranial blood may become so abundant that an anemic condition of the whole brain is produced. Such blood extravasation taking place gradually, it follows that the symptoms of pressure are also manifested by degrees. At first muscular spasms, combined with paralysis of the extremities of the opposite side, are observed, while later on the paralysis becomes general. These symptoms are then followed by loss of consciousness and considerable slowness of pulse. Contrary to commotion, the face appears red, the eyes shine, and the pupils are contracted. The quality of the pulse is full, but it may be below forty a minute at first; later on, it

becomes frequent. Finally, there supervenes an extreme slowness of respiration. Among the sequels epilepsy, caused by pressure upon the cortex, may be mentioned. Insanity also develops sometimes.

Cerebral contusion is due to the penetration of a bone-splinter or missile into the brain. If the penetrating force (bullet, stone) goes through the skull, there is generally considerable comminution, which is always followed by marked focal symptoms. Motor aphasia, for instance, points to injury of the left frontal convolution of the left hemisphere. When, in a case of gunshot wound in the temple, hemiplegia is observed on the other side, destruction of the motor centers is to be assumed.

When modern firearms were introduced, it was predicted that injuries in war would be more humane than they had been. The size of the new bullet being reduced from 0.7 to 0.3 inch, its rate of projection increased from four to six hundred inches a second, and its penetrating force being made about six times greater, it was believed that the thinness and the great force of the bullet would cause a clean, round, canal-like foramen. This was proved to be an error by the experiments of the author made in February, 1896, at Governor's Island, N. Y. As soon as the author had a chance to utilize Röntgen's discovery, he studied the form and degree of destruction produced by the new army rifle (Kräg-Jörgensen) in the following manner: Thanks to the courtesy of the officer in charge at Governor's Island, the author was enabled to skiagraph leg and skull immediately after they were shot at by a soldier of the garrison at various distances. Contrary to all theories, the bones as well as the soft tissues

showed the most destructive effect. Compare, for in stance, figure 136, which shows the tibia at its lower third transformed into a mass of bone-splinters.

If a bullet enters the cranial cavity, the intracranial pressure is immensely increased, an explosive effect taking place.

No doubt the lateral transmission of the energy of the bullet, at least in a zone of 350 meters, produces extensive comminution, and while the tribute of admiration is due to the genius of the inventor of the new instrument of destruction, humanity itself has no reason for triumph.

Paralysis of the hypoglossus or facial nerve implies a contusion of the correlative centers of Rolando's sulcus, while paralysis of an arm or a leg means an injury of the adjacent centers (central sulcus).

The relations of the outer wound itself to the supposed intracranial injury have, of course, to be taken into close consideration. If, for instance, there is a paralysis of the facial nerve, destruction of the center of this nerve is to be assumed, provided the situation of the outer wound proves that the nerve itself could not have been injured. In such a case the functional disturbance must necessarily be due to an intracranial injury.

There are, however, puzzling reports of cases in which, in spite of extensive injury to the brain, focal symptoms were absent. The author, for instance, observed a case in which a thin knife was thrust into the left upper eyelid of a man of thirty-two years. The wound was closed in two days. No reaction being observed, the patient attended to his business as usual. Six days later nausea and vertigo, followed

by convulsions, set in. When the author saw the patient on the following day, delirium had supervened. An immediate operation was advised, but before the family would consent to it, the patient died. The autopsy revealed the presence of an abscess at the base of the brain, the blade of the knife having pierced the roof of the orbit. The lower surface of the anterior lobe also was pierced by bone-splinters and transformed into a pus-focus.

In summing up, it is evident that for commotion the *sudden* loss of consciousness and the small pulse, for compression the *gradual* loss of consciousness and the full, slow pulse, and for contusion the well-marked *focal* signs, are most characteristic.

Simple fractures, not combined with any cerebral injuries, usually heal within four weeks. In commotion perfect recovery generally takes place also. But in compression caused by hemorrhage from the arteria meningea media the result is fatal in the great majority of cases. In contusion perfect recovery may also take place, if the extent of the lesion is quite limited; but in by far the greater majority of cases grave functional disturbances remain or an abscess forms. Epilepsy, defective memory, and even insanity may develop. Epileptiform symptoms may be caused by pressure conveyed by protruding bone-tissue in badly wasted fractures.

The **treatment** varies according to the character of the injury. Simple fractures heal without any treatment. In commotion a stimulating therapy, such as is employed in shock, is indicated. The author recommends especially for this purpose the methodic and frequent hypodermic infusions of normal salt

solution. The subcutaneous injection of camphorated oil and atropin is also advisable.

Grave cranial injuries require the most rigorous operative interference. In compression temporary resection, followed by the removal of the blood-clots and ligation of the arteria meningea media, must be performed without delay. In open fractures the most

Fig. 159.—Transverse fracture of frontal bone, sustained fifteen years ago by a man twenty-five years of age. (Compare Fig. 161.)

thorough asepsis (see p. 51, on Compound Fractures) is required. Especial care has to be taken in removing all foreign bodies—as, for instance, bone-splinters; also hairs that may have been carried along with the foreign body, since they are effective carriers of infection. The dura mater must always be thoroughly exposed.

Of course, bone-splinters can be removed only when the external opening is sufficiently wide. For widening the opening different means may be employed: A chisel and cutting bone-forceps are used for enlarging the fractured area. (See Fig. 164.) When, after thorough exposure, a splinter-fragment or a foreign body is located, it is seized with forceps and carefully extracted. (Fig. 163.) If a fragment is tightly adherent to the dura mater, it should never be extracted by force, but must be liberated by incising the dura mater. An impacted fragment is relieved best by

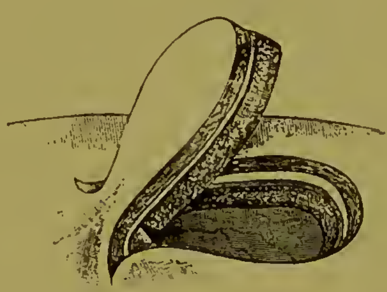

Fig. 160.—Formation of flap.

making an additional opening in the immediate vicinity (Fig. 165) in order to introduce a lever there which permits of thorough lifting. Depressed fragments the connection of which with the periosteum is well preserved are simply lifted with a periosteal elevator.

If the bone is intact, or if there is only a fissure, or in case a fracture with little depression is present, or if a small foreign body is to be extracted, the old trepan or an electric saw is to be preferred. The ingenious apparatus advised by Seneca D. Powell (Fig. 162) is especially useful in such cases.

In suitable cases the osteoplastic resection of the

skull can be done by forming a bone-flap. The technic of this operation consists in dissecting the soft tissues down to the periosteum in the form of a Greek Ω. (Figs. 160, 161.) The edges of the flap will retract somewhat. At the margin of the skin-flap the periosteum

Fig. 161.—Osteoplastic resection, showing scar produced by the injury, and also line of incision for osteoplastic resection in case illustrated by figure 159.

is incised and a groove is chiseled into the bone in the same line in which the bone-flap had retracted. The groove can also be formed by Powell's saw. (Fig. 162.)

The groove should be made in an oblique direction

so that the outer table rests on the inner when it is returned again into place.

If an elevatorium is introduced underneath the bone-flap, the latter can be raised and infracted, so that the whole flap may be turned back, the soft tissues serving as a hinge.

In all operations in the skull the incisions should be made longitudinally whenever possible, according to the direction of the arterial branches. If a transverse

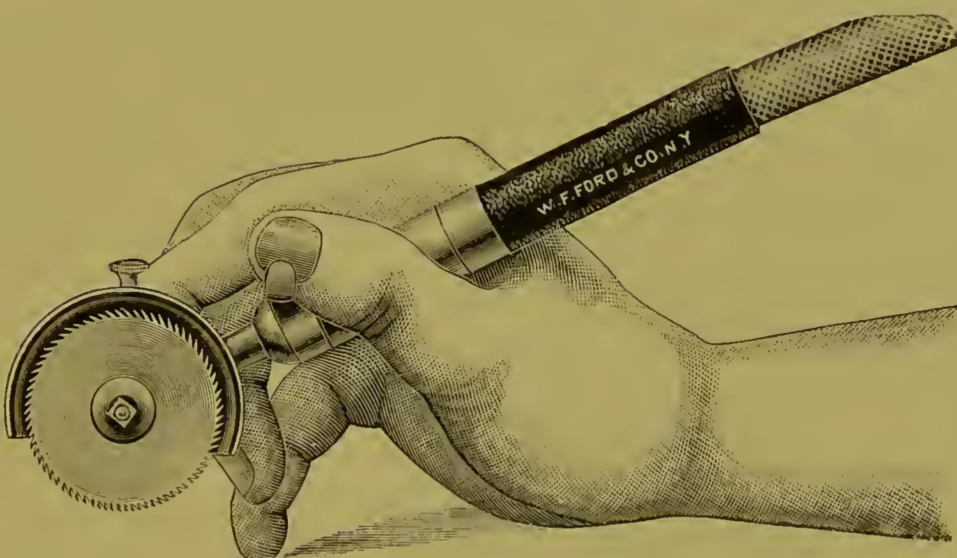

Fig. 162.—S. D. Powell electric saw.

(T-shaped) incision must be added, the upper end of the longitudinal incision should be selected for it, since the arteries are so much smaller the nearer they are to the vertex.

It goes without saying that the same principles apply to the flap operation.

In suppurative meningitis, in encephalitis, or in cerebral abscess free exposure of the foci is always indicated.

Skiagraphy is of great value in fractures of the vertex. In the case illustrated by figures 159 and 161

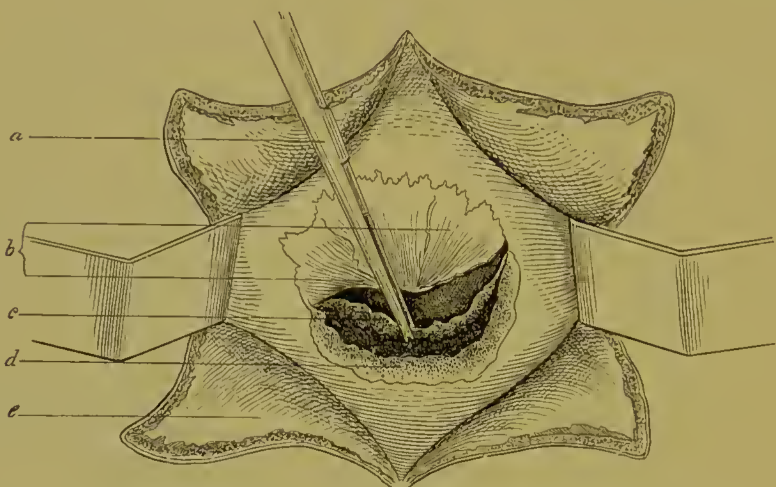

Fig. 163.—Removal of deep-seated splinters. *a*, Extracting forceps; *b*, superficial and depressed splinters; *c*, deep-seated bone-splinter; *d*, bone-margin from which the splinters were removed; *e*, reversed skin-flap.

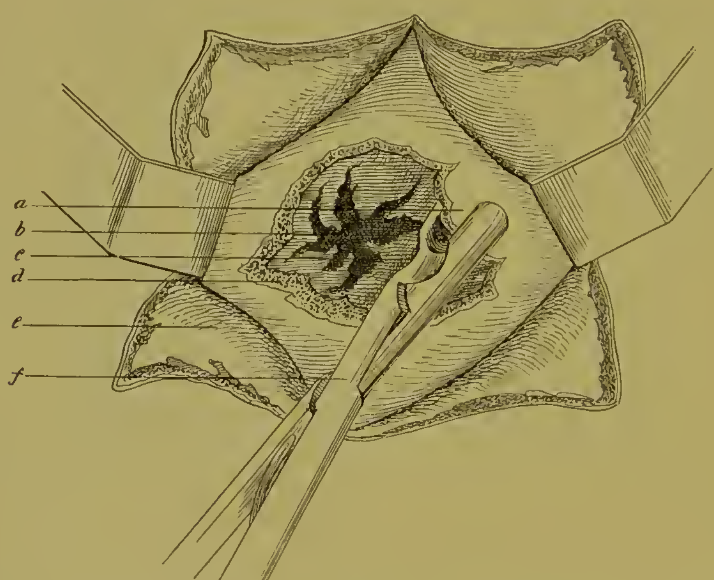

Fig. 164.—Enlarging fractured area by cutting forceps. *a*, Protruding bone-portion to be removed by forceps; *b*, lacerated dura mater; *c*, intact dura mater; *d*, wound-margin of injured bone; *e*, reversed skin-flaps; *f*, cutting forceps.

the depression of the outer and the protrusion of the inner table could be well demonstrated by the author.

As the patient suffered from epileptiform attacks after the injury, which was originally taken for a superficial lesion only, osteoplastic resection was performed fifteen years later. The condition found at the operation verified the correctness of the skiagraph entirely. The attacks have since stopped (time of observation after operation, one year).

The extracranial as well as the intracranial location of bullets has ceased to offer technical difficulties. If

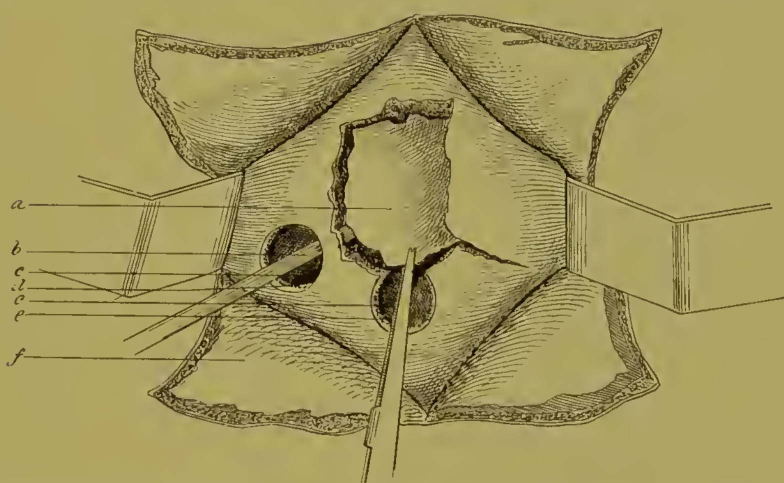

Fig. 165.—Relieving of impacted fragment. *a*, Fragment; *b*, elevator; *c*, dura mater; *d*, opening trephined for introduction of lever; *e*, trephined opening; *f*, reversed skin-flap.

bullets are situated in the bones, two skiagraphs at least are required—one to be taken anteriorly or posteriorly and the other laterally. By simply crossing their diameters diagonally the distance from the outer surface can be determined. The same principles of localization, more or less modified, apply to the intracranial localization of bullets.

In extracting a bullet the author found it useful to measure the distance of the bullet from the nearest

bone prominence in both skiagraphs; also to compare the skiagraph with the features of a normal skull.

In the case illustrated by figure 158 a bullet had entered the right temporal region, and, by passing the orbit transversely, caused traumatic enophthalmos (injury of the sympathetic roots of the ganglion

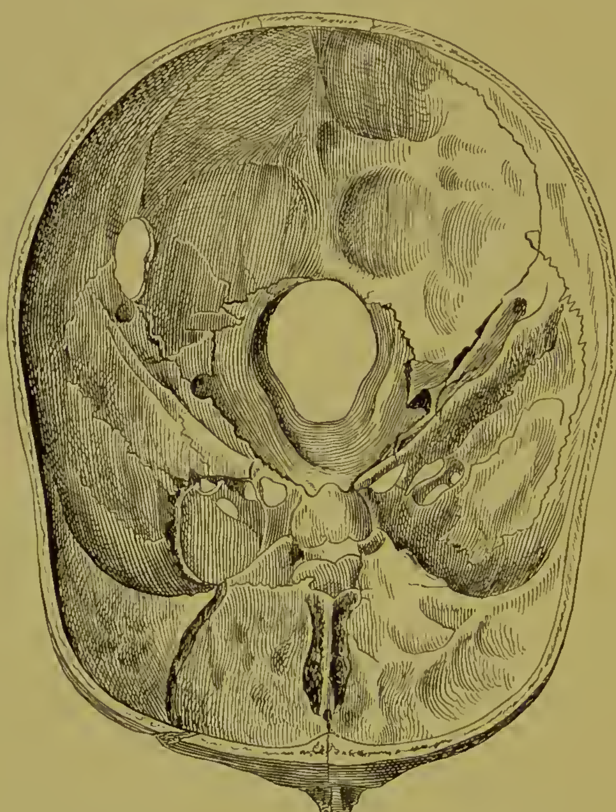

Fig. 166.—Fracture of the base of the skull.

ciliare?). The optic nerve was pierced and considerable hemorrhage of the choroidea and retina had taken place. Neither the comminution of the orbit nor any injury within the extent of the left antrum Highmori, through which the bullet had taken its course, could be demonstrated by the rays, but the bullet itself was

located in the left pterygoid process. The distances were measured during operation simply with a graded probe first, the distance between the nasal bone and the bullet being taken at the first skiagraph, which determined the direction and extent of the skin incision, and then the same distance being taken from the side skiagraph, which dictated the depth of the incision. Although the bullet was embedded in the bone and was surrounded by new bone-tissue, it was not difficult to detect and extract it, after the antrum Highmori had been exposed by osteoplastic resection of its anterior wall. Without the aid of the rays it would have been impossible to trace the bullet. In fact, it was a surprise to the author that it had taken so long and destructive a course without showing any other symptoms than a dull continuous pain all over the skull.

The bullet was so much compressed that it had altered its longitudinal form into a flat disc, which explains the shape of the bullet in the skiagraph.

FRACTURES OF THE BASE OF THE SKULL (Fig. 166) are, with the exception of gunshot fractures, always caused by indirect violence (fall, blow). In many instances a fissure only is produced, the seat of predilection being the lateral margins of the foramen occipitis. From there the fractures often radiate toward the sphenoid and the squamous portion of the temporal bone.

Most fractures of the base are simple continuations from the vertex, the force, for instance, being applied to the forehead and the fracture radiating to the base.

Strictly *local* signs are absent; a fact which is well explained by the concealed situation of the fractured area.

Signs.—Among the *general* or indirect signs the most important one is hemorrhage from one ear or from both ears in consequence of the fracture of the petrous portion of the temporal bone and the simulta-

Fig. 167.—Fracture of the nose, showing considerable upward displacement, in a man twenty-eight years of age (two days after the injury).

neous laceration of the tympanum. Sometimes hemorrhage from the nose (ethmoidal bone) and pharynx (sphenoid body) are also observed.

If the fracture is situated far anteriorly, sometimes ecchymosis develops gradually in the ocular region, especially in the bulbar conjunctiva. In case of considerable blood extravasation there is also slight exophthalmos.

Sometimes there is a considerable escape of cerebrospinal fluid, the reaction of which is most characteristic, inasmuch as it shows the presence of sugar, of small quantities of albumin, and of a large amount of salt.

There is often paralysis of the facial, auditory, oculomotor, trochlear, and abducens nerves (strabismus). A thorough examination with the ophthalmoscope not infrequently reveals conditions explained by the presence of blood extravasation in the sheath of the optic nerve, which is often produced by fractures within the extent of the optic canal.

There may, besides, be those signs of cerebral commotion, compression, and contusion that have been discussed in connection with fractures of the vertex. (See p. 252.)

So far skiagraphy could be relied upon in this fracture type only if the injury was well marked and was situated anteriorly.

The **prognosis** of fractures of the base is extremely unfavorable; infection, as well as destruction of vital areas within the brain, producing fatal meningitis or encephalitis. In the rare event of recovery there usually remains paralysis within the extent of the injured nerve sphere.

From an anatomic consideration of the fractures of the base it becomes necessarily evident that they are beyond direct surgical reach. The treatment must be conducted upon general principles, rest and artificial feeding being the main factors to be considered. The discharge of blood and of cerebrospinal fluid must be watched. The meatus should not be irrigated, but must be protected with a thick idoform gauze dressing,

which is kept well saturated with a strong bichlorid solution.

The **treatment** of the cerebral symptoms falls under the same considerations as those that have been treated of under fracture of the vertex. (See p. 257.)

FRACTURES OF THE FACIAL BONES

are mainly those of the nasal bones, the superior maxilla with the zygoma, and the inferior maxilla.

Fractures of the nasal bones (Fig. 167) are caused by direct violence (sometimes by a fall upon the nose ; more frequently, by a blow with the fist or a stick). In far the greater majority of cases the nasal bones themselves and the vomer, but sometimes also the nasal processes of the superior maxilla, as well as of the frontal bone, are involved. Very rarely fractures of the lacrimal and turbinated bones and of the cribriform plate of the ethmoid bone are observed.

In children fracture of the nasal bones is often caused by diving into shallow water.

The *signs* consist in ecchymosis of the nasal dorsum and in more or less profuse hemorrhage from the nasal cavities. There is always backward displacement of the fragments, so that the shape of the nose becomes flattened (traumatic saddle-nose). If the vomer participates, lateral displacement of the nasal frame is also produced.

The extensive ecchymosis often veils the nature of this injury. If a fracture is suspected, anesthesia is advisable.

The *treatment* consists in exact reposition, which is best accomplished in the following manner: A dress-

ing forceps, the branches of which are kept closed, is introduced and pushed against the inwardly displaced fragments. The manipulations of the forceps are controlled from without by gently pressing the fingers of the left hand on the nasal dorsum. If there should be very much displacement, reposition must be tried by introducing the forceps-branches separately and then compressing the septum in such a manner that the deformity becomes corrected. The reduced fragments are kept *in situ* by "intranasal splints," which

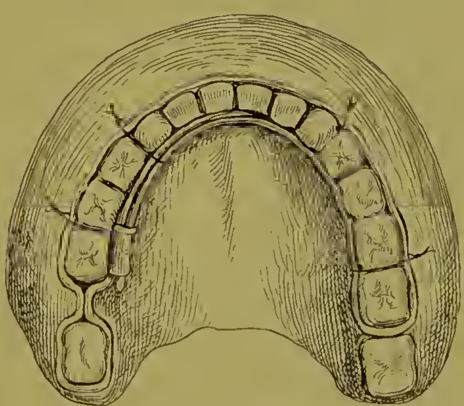

Fig. 168.—Dental splint.

should consist of rubber drains. They are retained by packing iodoform gauze around them and are secured by small safety-pins. If the latter are affixed to the drain-ends, just where they emerge from the nasal cavities, they serve as a supporting bridge, held in place best by rubber adhesive-plaster strips.

If union should have so taken place as to produce deformity, correction can be made by separating the old fracture-lines again with small chisels and nasal bone-forceps. The traumatic saddle-nose can only be

corrected by partial rhinoplasty, as suggested by Czerny.

Fractures of the superior maxilla and the

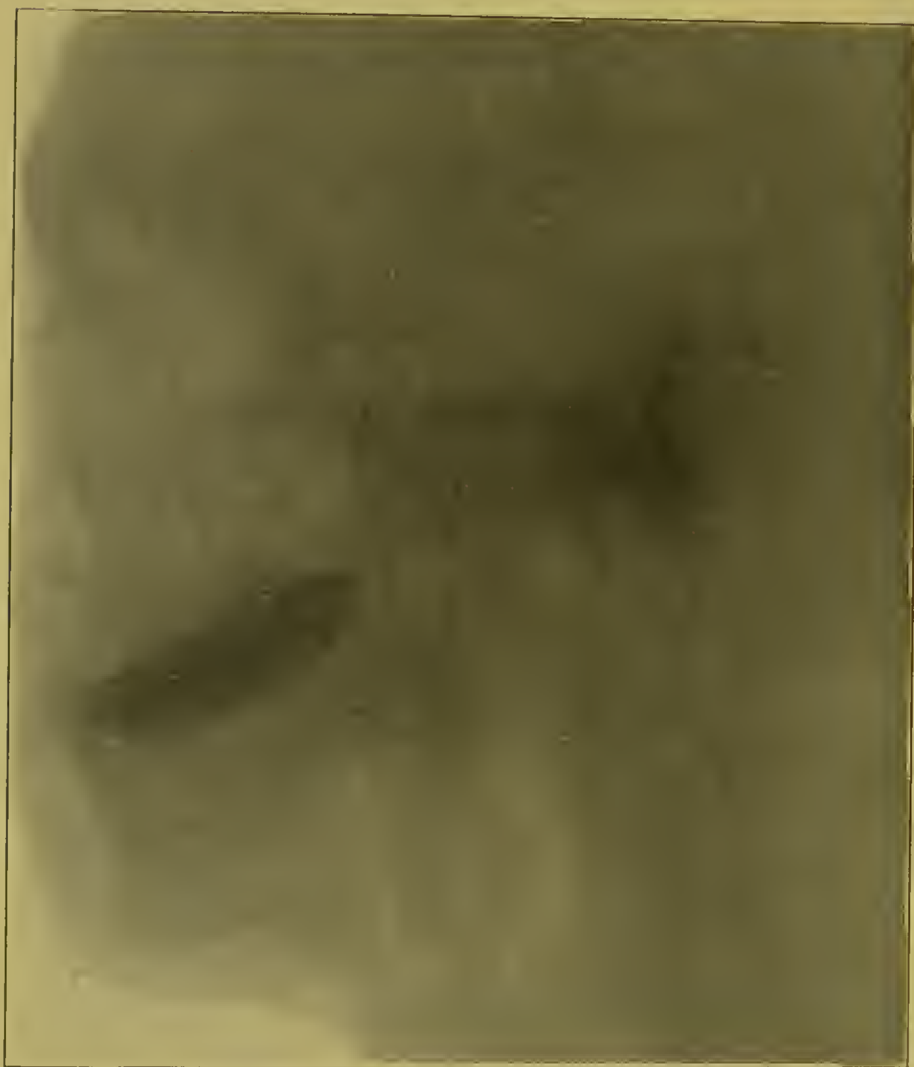

Fig. 169.—Fracture of the alveolar process, caused by a fall from a locomotive on a rail, producing great functional disturbance; man fifty years of age.

zygoma are caused by direct violence (blow by heavy and blunt force—stone, club, base-ball, horse-hoof).

The *signs* are always well marked; depression,

abnormal mobility, and crepitus being present. The line of fracture may be either vertical or transverse.

The most frequent type is the fracture of the alveolar process, in which the fragments are driven toward the oral cavity. They sometimes remain in loose connection with the maxilla, being attached by a small bridge of alveolar tissue. (Fig. 169.)

The *treatment* in all instances consists in reposition, except where the fragment is impacted between the adjoining bones. External wounds being present in

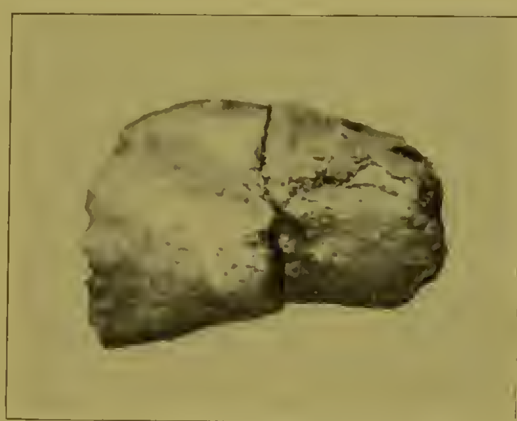

Fig. 170.—Transverse fracture of zygoma, caused by a fall from a carriage upon the edge of the sidewalk, in a man of thirty-five years.

the greater majority of cases, it is evident that great attention must be directed to thorough asepsis. In gunshot wounds the extraction of splinters has to be considered.

Graefe's head-band, which holds the alveolar process on a grooved steel bar, was formerly the favorite immobilizing medium, but modern practice gives the preference to a dental splint. (Fig. 168.)

Fracture of the zygoma (Fig. 170) without displacement should simply be treated by rest. But if the zygomatic arch is entirely severed from its connections

with the maxilla and from the frontal and temporal bones, the considerable displacement resulting therefrom requires thorough reposition. In such cases the injury may extend to the orbit. The author observed a case in which pressure of the depressed zygomatic fragment had caused comminution of the orbit, followed by intracranial abscess formation.

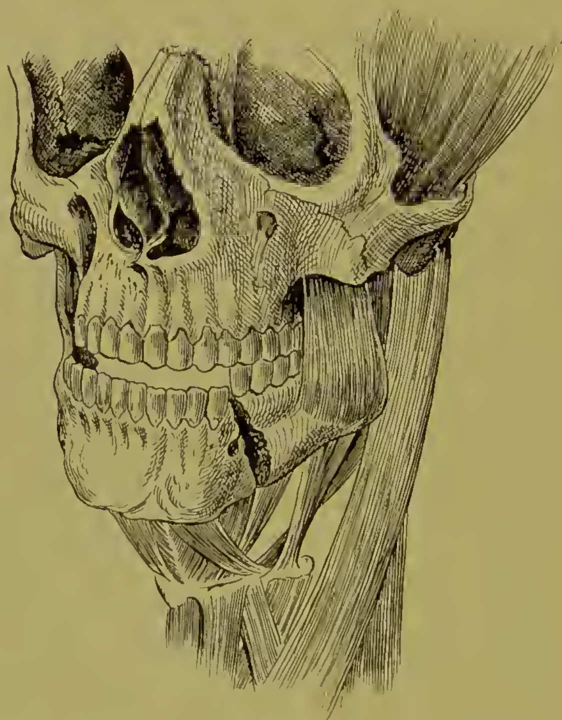

Fig. 171.—Fracture of the inferior maxilla.

Fractures of the inferior maxilla (Fig. 171) are frequent, and concern its arch in the great majority of cases. They are always caused by direct violence (blow—horse-hoof, stone—or gunshot wound). By indirect violence (fall on the chin or simultaneous compression of both mandibular angles) they are produced but rarely.

In children they are uncommon.

The head, neck, and coronoid process of this bone are but seldom fractured.

The *signs* are always well marked. There is con-

Fig. 172.—Fracture of mental portion of the inferior maxilla in a girl of eleven years, well united, four weeks after the injury.

siderable displacement and functional disturbance. Mastication is impossible, deglutition becomes im-

paired, and articulation is indistinct. The saliva is profusely discharged from the oral cavity, which is generally kept wide open.

The *treatment* consists, first of all, in exact reposition. Immobilization is best accomplished then by dental splints made of gold or aluminium molded after a plaster-of-Paris cast. (Compare Fig. 168.) If there be but little tendency to displacement, the fragments can sometimes be kept together by winding silver wire around the nearest teeth. In such cases a supporting splint of moss-board, which surrounds the whole external surface of the mandibular area, does good service. (See p. 66.)

In the absence of teeth wiring of the fragments has to be resorted to. (See p. 69.)

Since these fractures are of a compound character, the alveolar tissues always being more or less injured, great attention must be given to the most rigid observation of aseptic principles. Accordingly, careful cleaning of the teeth, frequent application of a disinfecting mouth-wash (salicylic acid, 0.2 per cent.), and iodoform gauze packing of the wound-cavities are the main therapeutic factors.

The diet should be liquid until union becomes perfect.

If asepsis is not carried through in the most rigid manner, infection may cause suppurative periostitis and osteomyelitis, followed by bone-necrosis. It should be remembered that in oral suppurations the respiratory organs are constantly exposed to the danger of infection, many cases of non-complicated fractures of the inferior maxilla having ended fatally on account of pneumonia (Schluckpneumonie).

Fracture of the Larynx.—Fracture of the larynx is peculiar to the age beyond forty, that being a period of life in which the laryngeal cartilages begin to calcify. The injury in question affects the thyroid cartilage in the great majority of cases, fractures of the cricoid and arytenoids being extremely rare. It is nearly always caused by direct violence (blow while wrestling, attempted strangling).

Fracture of the thyroid cartilage may be either unilateral or bilateral.

The *signs* consist in ecchymosis, in more or less deformity, and in abnormal mobility. Crepitus is generally absent, but there is always functional disturbance, the severity of which may vary from slight discomfort to dysphagia and dyspnea. Laryngoscopy generally reveals laceration in the mucous membrane and submucous hematoma.

The *treatment* must especially take into account the dangers of dyspnea. Intubation should be performed without delay. When there is considerable displacement of fragments, causing endolaryngeal extravasation and consequent edema, tracheotomy should be resorted to. In the treatment of the sequelæ cicatricial stenosis has to be mainly considered. If such a stenosis should supervene, the permanent employment of a tracheal tube will become necessary.

Fracture of the Hyoid Bone.—Fracture of the hyoid bone is produced by the same causes as that of the larynx. It generally takes place at the junction of the corpus with the cornu majus.

The *signs* are also similar to those of fracture of the larynx, but they are usually much less severe, slight hemorrhage from the mouth, hoarseness, painful

articulation, and deglutition being generally present. Sometimes dyspnea becomes considerable.

The *treatment* consists in manual reposition, the surgeon's left index-finger reducing the fragment while counterpressure is exerted from the outside by the right index-finger and the thumb. If reposition can not thus be accomplished, an external incision must be made upon the fragment, which can then invariably be reduced by a sharp tenaculum, which secures it during the reducing manipulations.

The patient must be fed by means of an esophageal tube for at least two weeks, and should be directed to keep silent.

APPENDIX.

THE PRACTICAL USE OF THE RÖNTGEN RAYS.

THE art of skiagraphy can be mastered only after a thorough study of the numerous details of the various apparatus necessary for the production of the Röntgen rays. Its two first and greatest essentials are a *high electric current* and a *Röntgen vacuum tube.*

A high current can be obtained in different ways. At present three forms of mechanism are more or less in use: viz., the Ruhmkorff, a simple form of induction coil; the Tesla, or high-tension induction coil, and the static machine. The most efficacious for skiagraphic work is the Ruhmkorff induction coil, which is excited by means of a current derived either from a battery or from a so-called direct current (city supply). A suitable battery, which furnishes a steady current, is the so-called Edison-Lalande cell-battery. For use when traveling, storage batteries may be preferred, the great trouble, however, being that if they become exhausted at a distance from a city, they can not be recharged, while the Edison-Lalande cells can be recharged anywhere.

The *direct current*, of course, is far superior to any other source, since there is neither charging nor supervising necessary. And, last but not least, the direct

current never embarrasses the operator by proving to be inefficient. Accordingly, whenever possible, con-

Fig. 173.—*r*, Rheostat; *l*, lever; *s*, adjustable stand; *h*, handle; *w*, wheel of motor apparatus; *a*, anode; *c*, cathode.

nection with the 110- or 120-volt direct current should be made.

The stronger the coil, the more efficacious the rays, as a rule. While good skiagraphs can be obtained by small apparatus that give a spark of the length of only six inches, in general large coils giving a spark-length of from 14 to 15 inches are to be preferred. An inductor of this power, with a 110-volt direct current, should afford a current-strength of from 1 to 2 amperes.

The reliability of a *Ruhmkorff coil* (Fig. 173) depends upon its thorough construction, and especially upon the proper quality of the wires and the accurate proportion of the windings of the primary and secondary coils. Of special importance is the thorough insulation of the primary from the secondary coil, since any leakage would cause sparking, and would consequently destroy the coil.

Into the interior of the coil a condenser is placed for the purpose of intensifying the result.

If the apparatus is used in connection with a *battery*, a vibrator must be adjusted, which controls the periodicity of the vibrations. If attached to the direct current, the air-brake wheel should be used, which renders the use of a vibrator unnecessary. The *air-brake wheel* attachment (Fig. 173, *w*) permits great rapidity of change in the electric circuit, thus intensifying the electromotive force in the secondary coil. It consists of two tooth-wheels, the projections of which are brought into close contact with two flat brushes, which lead the current in and out, while the dentated wheels are rotated at a high speed by a small motor. This motor runs a pressure-blower at the same time, the air-blast from which is directed to a two-forked tube, through which it is led out again by two flat nozles

placed directly above the brushes. There the spark is blown out again by the air-blast as soon as it forms.

The current passing through the coil is controlled by a *rheostat.* (Fig. 173, *r.*) By combining this with the air-brake wheel apparatus the electromotive force in the secondary coil is augmented much more than it would be with a simple motor apparatus controlled by a shunt-board provision.

The best electric apparatus are made in this country. The *alternating current*, which is used almost exclusively in Europe, requires more complicated apparatus, so that its handling presupposes the experience of a professional electrician.

The most important factor, and the one upon the efficiency of which the success of skiagraphy largely depends, is the *tube:* the higher its vacuum, the more powerful and penetrating the Röntgen rays.

The *Röntgen tube* (Fig. 173) consists of a glass vessel, usually of an oblong or globular shape, from which the air is exhausted and into which the ends of electrodes are fused. With suitable exhaust pumps the rarefaction of the air in the tube can be brought as high as one-millionth part of the ordinary density. One of the electrodes ends in a disc of globular concave shape, which is made of aluminium; this electrode is called the *cathode.* (Fig. 173, *c.*) The other ends in a disc of flat shape, which is of platinum; this is called the *anode.* (Fig. 173, *a.*) The anode is situated opposite the cathode at an angle of about forty-five degrees. Its shape may be circular as well as square. Almost all of the modern tubes also contain a second anode, which is connected with the main anode (platinum). (Fig. 173, *a.*)

One of the great difficulties encountered in the use of the tubes is due to their soon becoming inefficient on account of the permanent change of pressure that occurs within them.

In view of this variation of the intratubal pressure, tubes have been constructed that permit lowering and raising of the vacuum in the tube at will. Siemens found that the fluorescing air, with the vapors of phosphorus, iodin, and other similar substances, forms dense bodies, thereby diminishing the pressure within the tube. On the other hand, if the walls of the tube are warmed, the stratum of air that condenses on the glass surface is driven away, thereby intensifying the pressure. In utilizing this principle tubes with adjustable vacuum have been constructed, which are provided with an adjuster intensifying and diminishing the vacuum at will by lengthening and shortening the space between its spark-rods.

If currents of very high intensity are used, the platinum disc of almost all tubes becomes white hot after a short time (often after a few seconds). If thus kept glowing a little longer, the platinum melts. To obviate this most embarrassing occurrence, tubes have recently been constructed in which the metallic parts are very thick and resistant. Such tubes permit of a current of maximum intensity for about one minute; then the very marked outlines of the picture become less distinct, the tube filling with blue light at the same time, which indicates that it is overheated; the current must then be turned off without delay. Such tubes make a good skiagraph of the thorax, for instance, in forty-five seconds. Grunmach constructed tubes that permit the glowing metal

to be cooled by the intratubal circulation of a stream of cold water.

The best tubes are undoubtedly those that, when just purchased, show a red-hot focus at the platinum disc while a low current is employed. New tubes that show fluorescence only by using a high current should invariably be rejected. It is one of the main characteristics of a good tube that it stands intense glowing of the platinum disc without being impaired at once; in other words, that it stands currents of high intensity. A good tube must also furnish a uniform light.

The variety of tubes manufactured now in various parts of the world is very great. The best are made in Thüringen (Germany). It requires a vast amount of experience and repeated experimentation to select tubes suitable for the particular apparatus to be employed. So it must be considered that static machines require tubes with a special vacuum, while tubes prepared for a battery-set generally do not give satisfaction with an air-brake wheel apparatus or a Wehnelt interruptor, which permits the use of tubes of the highest vacuum obtainable at present.

The **vacuum** of the tubes is generally increased during their use, which necessitates a proportional increase of the intensity of the current. Therefore, even for inductors furnishing a very long spark, tubes with a low vacuum should be chosen, as the latter increases so much during use that at last the full power of the apparatus is required for producing an efficient light. Finally, however, the fluorescence of the tube ceases, even if the high current is employed. Then the vacuum can be reduced by heating the tube with an alcohol-lamp, while a weak current is used, until the fluores-

cence becomes distinct again. If this fails, the tube should be surrounded evenly and tightly by gauze compresses slightly moistened with water.

At last, of course, all these procedures will prove to be without avail. Some tubes regain their efficiency simply by being left untouched for a few weeks, but finally they all become useless for medical purposes. Then the resistance of the tube becomes so great that, while the interior hardly shows any fluorescence, most of the sparks go around the exterior surface of the tube.

The presence of purple or red light points to a leak, which naturally renders the tube inefficient. Leaky tubes may be repaired by sealing the defect.

The tubes must be preserved in a closet in which there is a uniform medium temperature. They should rest on padded shelves. Dust, which in the course of time always becomes adherent to the tube while in use, is to be wiped off by passing the dry palm of the hand gently over it.

The degree of intensity of the tubal light and the amount of penetration can be estimated by an experienced operator simply by holding his own hand before the fluorescing screen. For exact measurement, however, various kinds of *skiameters* have been devised, the principle of which consists in the attachment of small squares of tinfoil, of varying thickness, to a fluorescing screen. The difference of thickness is indicated by little figures, made of lead, which appear more or less distinct according to the thickness of their corresponding tinfoil. The author found it useful to construct a skiameter consisting of fifty staniol discs, according to the number of knobs at his rheostat. (Fig.

173. *r.*) To each disc a number, made of wire, is attached, which indicates the number of the staniol lamellæ. No. 1, for instance, contains one lamella only, while No. 50 contains fifty. That number which just permits of the recognition of the shade of its wire cipher indicates the degree of intensity of the tube.

If the rays fall upon a *screen* covered with fluorescing salts, such as tungstate of calcium, platinocyanid of potassium, or platinocyanid of barium, fluorescence is caused on it. The human hand, for instance, if placed between the tube and a screen evenly covered with one of the fluorescing salts, shows the condition of its bones distinctly. Even the soft tissues can be distinguished to some extent.

The use of the fluorescing screen is facilitated by attaching it to a suitable framework, formed like a stereoscope, the body of which is of tapering form. The large end of such an instrument, generally called *fluoroscope*, should contain a piece of cardboard, on the inner surface of which the fluorescent salt is distributed, while the small end has two apertures, formed in such a manner as to fit over the eyes of the operator.

With the fluoroscope a superficial examination of the objects can be made. Movable organs—as, for instance, joints, larynx, hyoid bone, or the intrathoracic viscera (especially the diaphragm, heart, and pericardium)—can be studied while moving or pulsating. But the numerous fluorescing impressions, succeeding each other with great rapidity, are apt to deceive the human eye wherever the features of the lesion are not distinctly marked; while fixation on a photographic plate gives all the details exactly. Therefore, fluoroscopy should be used in fractures as a preliminary

procedure only. It calls attention to the seat of the fracture, and determines the best position of the limb for proper fixation. Especially in joint fractures it will select that angle of flexion or extension in which the injured portion can be brought out best on the plate.

It is the *plate* only which shows the details of the fracture exactly and which permits of the thorough study of the various features of the fracture type. Its comparison with the normal skeleton will make the abnormalities evident at once and will help the surgeon to a thorough judgment of the case; and the value of a skiagraph for future information—sometimes for forensic purposes—should not be underestimated. Therefore, whenever exactness of result is desired, fixation on a *photographic plate* is to be preferred. The photographic technic can easily be learned.

The development of a skiagraphic plate is practically the same as that of an ordinary photographic one exposed to sunlight. There is no doubt that the anatomic knowledge of a physician makes him more fit to develop the important parts of a plate more intensely. It is, besides, a great advantage if the physician is able to develop the plates himself, since he is enabled to learn the result at once, while sending the plate to a photographer involves a great loss of time.

Notwithstanding this fact, the author, believing that a skilled operator can do more exact work than the medical amateur, prefers to have the valuable assistance of a professional photographer, and therefore has his plates developed by the most skilful experts available.

In taking skiagraphs properly a number of small details should be considered. First of all, it should

be borne in mind that it is a law, applicable to all elements, that the higher their atomic weight, the more energetic the absorption of the rays. The organic substances of the body, such as the salts of lime in the bones, absorb more light than the surrounding soft tissues, consequently they are but slightly permeable. The more lime-salts the bone contains, the less permeability exists and the more distinct its silhouette will be on the photographic plate. Compact bone-tissue thus shows a much more distinct picture than the medullary or spongy parts. (See Figs. 119 and 135.) The special structure of the different bones can be recognized so well, in fact, that the study of the transformation of bone-tissue is no longer based upon mere conjecture.

The organic tissues of the human body show permeability of a medium degree. The muscular layer of the heart, or of a hand or foot of ordinary size, has a permeability about the same as that of a liver or kidney of the same thickness. The tissues of the nerves and the blood-vessels are a little less permeable. This explains why in skiagraphs of the soft parts no particular variety of tissue, as of muscle, tendon, ligament, nerves, or vessels, is distinctly marked. When one or another tissue appears more distinct, this fact may be attributed mainly to the greater thickness of the mass of the tissue in question, and less to its own character. About the same degree of permeability is shown by hyaline cartilage and by normal blood as by that which is decomposed.

In a good skiagraph all kinds of metal (bullet, needle, nails), stone, wood, and glass will be shown. The weight of the smallest splinter of iron so far dem-

onstrated was 0.0202 gm. Calcified trichinæ also show easily.

All varieties of fractures and their complications, callus formations, and dislocations are representable.

After *osteoplastic resection* the result can be ascertained by the rays. Months after osteoplastic amputation of a leg the author was able to demonstrate the small bone-fragments which were bent inward from the cortex of the tibia and fibula for the purpose of making a solid stump.

The differentiation between *bony* and *fibrous ankylosis* is now as easy as it is important. (See Fig. 119.)

In the treatment of *congenital dislocation of the hip* the skiagram will determine what method of treatment should be chosen, as it reveals well the relations between the femur and the acetabulum. If the condition of the latter be unfavorable, bloodless reduction will be impossible, and a cutting operation must be performed. The skiagram will also demonstrate whether reduction of a hip dislocation was successful or not. It is true that after perfect reduction the head of the femur can be felt between the spina and the symphysis in the majority of cases, and also that the characteristic noise can be perceived while the head is jumping over the margin of the acetabulum. But, on the other hand, it can not be denied that the noise is often indistinct, and that the thickness of the muscles oftentimes impairs our judgment, so that it is the skiagram only which gives indisputable information.

In the various forms of *talipes* and in *floating bodies in the knee-joint* the rays are also serviceable.

Rachitic deformities can also be well represented. Particularly in *obstetrics*, the study of a rachitic pelvis is of great importance.

Differentiation is easily made between the osseous and articular changes in *acromegaly* and *osteoarthropathie hypertrophiante pneumique*.

The author has succeeded in obtaining undeniable signs of fracture of the *coccyx* in two cases of alleged coccygodynia. The conclusion is obvious that in most of the cases which were taken for coccygodynia, and which were preceded by trauma, a fracture or infraction had occurred.

Inflammatory processes—*spondylitis*, for instance—can easily be differentiated from fractures of the spinal column, and tubercular foci in the bones can also be represented. The same applies to *osteomyelitis* (see Fig. 142) and *necrosis*.

Iodoform-glycerin injected into tubercular joints can be recognized as a distinct shadow, and thus may sometimes give evidence of the extent of fistulous tracts.

The *cartilages of joints* are permeable to the rays; but if they atrophy on account of arthritic processes, a skiagram of the same appearance as that of ankylosis is obtained. The interspace always found between two bones of a joint under normal conditions has then disappeared. The differentiation between diseased cartilage and ankylosis is easy, as in the last event mobility is arrested.

Deficiencies of the skull, especially such as those caused by *syphilis*, are an interesting object for skiagraphy.

Differentiation between *simple arthritis*, *rheumatism*, and *tubercular* and *syphilitic* affections of the joints is also possible.

Foreign bodies in the skull or in the *eye* are easily reproduced.

Solid tumors, such as *osteomas, osteochondromas, osteosarcomas, enchondromas,* and *fibromas* are also well represented. In a case of *aneurysm of the thigh,* in which the entire absence of pulsation was a perplexing feature, the author failed to get any positive information as to the character of the tumor. Still, the rays were found to be of great value, inasmuch as they excluded several possibilities in the case —viz., osteoma, osteochondroma, and osteosarcoma— for which the hard immovable growth could have been mistaken. But, considering that in the event of the presence of a growth of this character the skiagraph would not have shown the outlines of the bone normal and distinct, they were excluded. In aneurysm of the thigh the thick femoral muscles of course veil the outlines of the aneurysm-wall, while the structure and outlines of the bone would distinctly show.*

In *thoracic surgery* skiagraphy has proved that after subperiosteal resection of a rib the exsected portion is always more or less re-formed.†

The extent of a *pyothoracic cavity* can be represented by filling it with iodoform-glycerin. The subnitrate of bismuth, which is not permeable by the rays, furnishes a still more marked contrast; but as it interferes with the treatment, its use can not be recommended by the author for this special purpose.

Pleuritic effusions show a marked opacity through the fluoroscope. The larger the amount of effusion,

* Compare the author's article on the difficulty of differentiating between femoral aneurysm and osteosarcoma in "International Clinics," vol. IV, Ninth Series.

† Compare the author's article on "Pyothorax," in the "International Medical Magazine," for January, 1897.

the greater the degree of opacity. In pyothorax the opacity is somewhat less complete than in serothorax. Especially on the right side, the outlines of the liver show a marked contrast to the lower boundary-line of the effusion. The upper boundary-line of the effusion generally appears convex, but if the patient inspires deeply, or if he coughs violently, it loses its convexity and becomes horizontal. By changing the position of the patient, of course, displacements of the effusion are observed accordingly. Uniform transparency above the effusion points to the result of a simple inflammatory process, while constant opacities of an irregular appearance justify a suspicion of beginning tuberculosis.

As a rule, it is found that the area of dullness corresponds to the area of the shadow. It is natural that the representation of *calcareous areas*, as well as of cavities, in tuberculous lungs should not be attended with any technical difficulties. *Mediastinal and pulmonic tumors* which on percussion did not show any dull area pointing to their presence are recognized. Swollen bronchial glands have also been diagnosticated by the rays. *Hypertrophied pleuræ* show a very distinct shadow, which is as thick as liver-tissue. This renders exploratory pleurotomy, advised by the author,* entirely unnecessary.

Hydropneumothorax may also be recognized by the rays, which show the very dark outlines of the exudation in contrast to the light shade of that intrathoracic area which contains air. The dark boundary-line of the exudation can be recognized by the fluoroscope as an ascending and descending line during expiration.

*See "Exploratory Pleurotomy and Resection of Costal Pleura," "New York Medical Journal," June 15, 1895.

The diagnosis of *subphrenic abscess*, formerly so difficult,* has become simple, the space between the diaphragm and the lower boundary-lines of the abscess showing distinctly. If situated between the diaphragm and the liver, the image is particularly distinct.†

The localization of *lung-abscess* is simplified by skiagraphing in different positions.

The *position*, *size*, and *shape* of the *heart* can be elicited. There is also no difficulty in differentiating aortic aneurysm from mediastinal tumor.

Indeed, as to type, shape, and size of any mediastinal tumor, much more reliable information can be obtained by skiagraphy than by percussion. In a case of *aortic aneurysm* ‡ the author could demonstrate not only complete atrophy of the sternum down to the xiphoid process, and of the sternal portions of the clavicle, but also the overlapping of the heart over the parasternal line and the downward displacement of its apex. The oval shape of the heart was distinctly recognizable, and was well demarcated from the aneurysm, the enormous intrathoracic extent of which was also clearly shown. Another skiagram of the same case showed the aortic arch.

The patient having succumbed to pneumonia six months after his case was demonstrated, the author had a chance to verify the correctness of the skiagrams by the autopsy.

* Compare the author's article on "Subphrenic Abscess," "Medical Record," February 15, 1896.

† Compare the author's "Beitrag zur Literatur der subphrenischen Abscesse," "Langenbeck's Archiv," vol. LII, No. 3; and "The Röntgen Rays in Surgery," "International Medical Magazine," May, 1897.

‡ Compare the author's article on "An Extraordinary Case of Aortic Aneurysm," "New York Medical Journal," April 15, 1899.

If we realize that the rays enable us now to recognize aneurysms at their earliest stages, it becomes evident that frequently a series of prophylactic measures can be employed which may counteract any further aneurysm-formation. The therapeusis then being under perfect control, it can be ascertained whether, under treatment, either improvement, arrest, or still further expansion may take place.

It is evident that in all these cases, especially in accumulations of fluids, the question of displacement of the heart is of great importance for diagnosis.

Bullets in the thoracic cavity are represented with difficulty. It is only when the patient possesses enough energy to inspire deeply and to retain breath for half a minute that a foreign body in the lungs or pericardium can be made visible.

The diagnosis of *arteriosclerosis*, while very easy on the surfaces of the body, was very difficult in the deeper tissues. According to the text-books on internal medicine, the thickening of the tunica intima can not be recognized if it be confined to a small area or to single small foci. It hardly need be emphasized how important it is to know whether, in a given case of sclerosis of the radial artery, for instance, there exist foci in other vessels besides. Nor can it be a matter of indifference what the number of these obstructive foci is, and whether a large artery, such as the aorta, or only a small one, such as the temporalis, is concerned. The presence of a large number of foci means a loss of propelling energy in the circulation, which can be compensated only by the increased working power of the left ventricle. The arterial pressure thus becoming higher, hypertrophy of the overworked

ventricle will be the most natural consequence. If such foci are recognized at an early stage, proper prophylaxis can accomplish a great deal in preventing secondary disturbances. The prognostic significance of an exact knowledge of the condition of the arteries is also evident. The Röntgen rays give us a most reliable method of ascertaining the condition of the vessels, and this in nearly every part of the body. In a case of sclerosis of both radial arteries the author studied the forearm, head, neck, and femoral and aortic regions skiagraphically. Nowhere did the conspicuously developed plates show any indications of degeneration of any artery except on the forearm. From the negative state of the other skiagraphs the author drew the conclusion that the patient's arteriosclerosis was confined to the radialis and anterior interossea—a limitation which harmonized with the good general condition and the absence of palpitation, dyspnea, and vertigo.*

Enchondroma of the larynx can be easily recognized. *Aneurysm* of the *carotid*, the *subclavian*, the *anonyma*, and the *abdominal aorta* are also representable.

In abdominal skiagraphy great progress has also been made recently. *Total transposition of the viscera* could be well represented by the author.† The stomach, the intestine, and the bladder are of equal translucency, and skiagraphs of these organs have to be taken *cum grano salis*. The much more solid masses of the liver, the spleen, and the kidneys can be well represented.

In a case of carcinoma of the pylorus in which the

* Compare the "New York Medical Journal," January 22, 1898.

† "Annals of Surgery," May, 1899.

author performed a successful pylorectomy, a distinct shade had been obtained.

To make the outlines of the *stomach* visible, the stomach may be filled with salts which are impermeable to the rays—subnitrate of bismuth, for instance. The author, however, prefers the introduction of a soft rubber tube the lumen of which is filled with mercury. Of course, in a tube of this kind an eye must not be cut out. A rubber tube containing thin, flexible steel wire in spiral form, advised by the author,* permits of rapid representation of the outlines of the stomach. The stoppage of this tube indicates its arrival at the large curvature of the stomach, and further propulsion shifts it alongside its wall. There the steel spiral is easily shown by the skiagraph. In *carcinoma* of the *esophagus* the author has tried the same experiment with smaller sounds, but, unfortunately, few patients are able to tolerate them for a length of time sufficient for good representation.

Hydronephrosis and *echinococcus* were reported as being recognized in connection with the usual diagnostic methods.

Renal and *vesical calculi* may also be skiagraphed. In the living subject, with the old vacuum tubes only such calculi could be represented as consisted of a hard and firm layer, like the oxalates, while the more penetrable urates left an indistinct shadow, and the translucent phosphates hardly showed at all. The success of skiagraphy in calculi of the urinary tract depended only upon the different chemic composition of the calculi, and consequently upon their greater or

* See "The Röntgen Rays in Surgery," "International Medical Magazine," May, 1897.

less opacity.* Now, with the new quick-penetrating tubes, more or less opaque shadows of all three different varieties can be obtained.

Gall-stones could not be skiagraphed until recently. It was the privilege of the author to show the first undisputed skiagraph of gall-stones in the living subject at the October meeting of the New York County Medical Association, in 1899. Gocht, Oberst, Rumpf, Dumstrey, and Metzger, who are among the best-known experts in skiagraphy, declared recently that biliary calculi could not be represented. The last-named is even responsible for the bold assertion that "nowadays nobody will any longer maintain that gall-stones can be skiagraphed"; that "all experiments in this direction have proved to be failures"; and that "it appears hopeless that such experiments will give any other result in the future." But *errare humanum est!*

After many trying disappointments the author succeeded for the first time in skiagraphing the cholelithiasis of a woman seventy-two years of age, after having employed four different photographic plates at the same time. The upper plate, situated directly below the region of the gall-bladder, showed the outlines of the liver well, while in the fourth and remotest plate it appeared only faintly; but the calculi were clearly represented. The next exposure was made with a quick-penetrating focus-tube on a single plate, and lasted ten minutes. After it was found how long it took with this tube to represent the liver and the os ilii, a second plate was exposed, this time for six

* Compare the author's previous publications on this subject: "International Medical Magazine," May, 1897; and "American Journal of Cutaneous and Genito-urinary Diseases," January, 1899.

minutes only. This second skiagraph showed the denser tissues less clearly, while the calculi were much more distinct. An exposure lasting seven minutes, one for eight minutes, and one for nine minutes were also made, all showing that the longer the time of exposure, the clearer the denser tissues and the obscurer the calculi appeared. It thus became evident that one exposure is not sufficient to determine the length of time required by each *individual* tube for the representation of each individual gall-stone type. A test should therefore be made first by making a short as well as a long exposure in a case of suspected cholelithiasis; that is, an exposure of about four minutes as well as one of nine or ten. The most powerful focus-tubes at present attainable should be chosen for the purpose. By comparing the results the proper time of exposure for the best results can be estimated. For better identification the contours of the organs, especially the liver, should be outlined by thin wire attached to the plate before the final skiagram is taken.

The results, of course, are to some extent dependent upon the *chemic composition of the biliary calculi*, which is far more complex than that of calculi in the urinary tract. All the different types of calculus were skiagraphed by the author on a photographic plate, in order to obtain a visual comparison of their permeability. The same calculi were then irradiated through the living body, thus practically demonstrating the difference in translucency. The common biliary calculi, the most frequent type, were found permeable to the rays, and therefore produced a light shade only. If present in large numbers, the shade was somewhat more conspicuous. Calculi composed of pure choles-

terin are less permeable to the rays than the common type, and show a slightly more distinct shade.

The stratified cholesterin calculi, on account of their admixture of calcium, show much less permeability to the rays, wherefore a distinct skiagraph can be counted upon.

The mixed bilirubin calculi, which, besides bilirubin-calcium, contain traces of copper and iron, are less permeable to the rays than all the former varieties, and consequently give a very distinct shade. The same applies to the pure bilirubin-calcium calculi.

In *skiagraphing the gall-bladder* it is necessary that the patient should lie on his abdomen with a pillow underneath his symphysis as well as underneath his clavicle. The elevation produced by these pillows permits the protrusion of the region of the gall-bladder, thus bringing the calculi nearer to the photographic plate. The approximation is increased by turning the body slightly to the right and raising the left side.

Another point of importance is that the rays should not penetrate the abdomen in a vertical direction, but from the side, so that the thick and less transparent tissue of the liver is not permeated in its whole diameter. The direction of the rays should be such that they form an angle of about sixty degrees with the plate. The tube must be as near the abdomen as possible.

By employing this method, not only the size, shape, and diameter of the gall-stones can be determined, but they can also be localized. How important it is to know whether there are also calculi in the liver besides those present in the gall-bladder! Calculi in the com-

mon duct can also be shown, while formerly it was only after extensive exposure by laparotomy that such diagnosis could be made with any degree of certainty. Exploratory laparotomy for suspected cholelithiasis will hardly be necessary any more.

If medical treatment of cholelithiasis is tried on the basis of a skiagraph, it can be ascertained by subsequent exposures whether any calculi were dislodged or whether some had escaped into the duodenum. The same applies to the state of the intrahepatic calculi. If the calculi prove to be of very large size, their removal by medical treatment can naturally not be expected.

Since his latest publication* the author has had frequent opportunities to skiagraph biliary calculi, and with the improvement in the routine, the skiagrams became much clearer. In a case of cholelithiasis in which cholecystotomy was performed by the author, pure cholesterin calculi were found, which, in spite of their transparency, had made a well-defined shadow on the plate before operation was resorted to.

The question whether or not an operation should be performed in cholelithiasis can thus be definitely settled by the Röntgen rays. When small stones are represented, there is a chance for medical treatment. When stones are found too large to pass the common duct, medical treatment can only be of a palliative character, and cholecystotomy should be performed as soon as the calculi prove to be a source of irritation.

As previously mentioned, an excellent tube is the

* "On the Detection of Calculi in the Liver and Gall-bladder," "New York Medical Journal," January 20, 1900.

conditio sine qua non for skiagraphic success in such delicate work. But even the best tubes differ in their qualities, and must, therefore, be studied and, so to say, *individualized*, as different patients are to be judged differently, although suffering from the same disease. Absolute laws can therefore not be made. (Compare p. 305.) In general, it may be said that the more translucent a calculus, the shorter must be the exposure; therefore the pure cholesterin calculus requires a shorter exposure than one containing calcium. But the great trouble is that when skiagraphing for suspected calculi, we do not know beforehand what may be the chemic composition of the alleged stones, and therefore we do not know what time of exposure will be the most desirable. This difficulty can be overcome to some extent by making a minimum and a maximum exposure at the same time. If a short exposure reveals the presence of calculi, while a long exposure, made at the same time, is negative, the probability is that a translucent calculus (cholesterin) is present. If a short exposure proves to be positive and a small one negative, a dense calculus may be inferred.

Even a poor negative, if it shows nothing but the faint outlines of elliptic and faceted bodies in the region of the gall-bladder, is authoritative. Sometimes the negative shows nothing but the calculi. They must always be most carefully studied, because the inexperienced eye often will not recognize the calculi, which are evident to the trained eye at a glance.

All authors agree that one of the greatest difficulties encountered in the treatment of *spina bifida* has been the fact that its various types—viz., simple meningocele, myelomeningocele, and myelocystocele—could

not be differentiated. Especially, the distinction between meningocele and myelocystocele has been generally impossible. Considering only the one point that in meningocele aspiration should be tried first, while in the other varieties extirpation must be resorted to, the importance of the question is self-evident. The skiagram now shows with absolute distinctness whether or not there is an opening in the spinal column ; it shows also the presence or absence of the nerve-substance, and sometimes even its expansion in the sac. In those rare cases in which the presence of lipoma or fibromyoma is in question it is again the skiagram which gives the needed information.*

Soon after the utilization of Röntgen's discovery, reports of extensive *dermatitis* and *gangrene* of the integument were published, which disturbed the public mind in a deplorable and unjustifiable manner. But, especially since the time of exposure is now so much shorter than during the earlier stages of the art, the possibility of originating skin irritation is extremely small.

It is undeniable that a peculiar trophoneurotic idiosyncrasy may exist in some individuals, but in the great majority of known cases the burns of the skin were caused either by the ignorance of the unskilful operator, the tube often being too near the object, or by too prolonged and too often repeated exposures. It is not surprising to observe such accidents so long as laymen, such as opticians and instrument-makers, who understand nothing of the anatomy and physiology

* Compare the author's article on "The Röntgen Rays in Spina Bifida," "Medical Record," August 13, 1898.

of the skin, are intrusted with "the manufacture of skiagrams."

As in many other respects, the question of *proper dosage* must also here be perfectly understood by the operator. A person who irradiates a patient suffering from sycosis every day intensely for a whole hour, irrespective of the reaction following such a radical procedure, so that gangrene occurs, has just as little business to do skiagraphic work as a shoemaker has to prescribe morphin.

Since February, 1896, the author has made nearly three thousand skiagraphs, and has never observed the slightest irritation of the skin in any case in which the rays were used for diagnostic purposes. In two cases only was circumscribed depilation observed. In both patients the skull had to be skiagraphed frequently and at short intervals (one was the case illustrated by Fig. 161, and the other that shown in Fig. 172). In the first case depilation began after the fifth, and in the second case after the sixth, exposure. In both instances the hair was perfectly restored three weeks afterward.

Changes in the pigmentation of the integument or in the growth of the finger-nails, congestion, inflammation, and necrosis of the skin are reported. Some operators have observed cessation of perspiration on the dorsum of their hands. The source of such tissue-changes is like that of other burns produced by electricity.

It was not more than natural that these properties of the rays were soon utilized for *therapeutic purposes*. Cases of *hypertrichosis*, of *nævus vasculosus*, of all the various types of *eczema*, *psoriasis*, and *syco-*

sis, have been reported as cured by the rays. There can also be no doubt that *parasitic skin-diseases*, such as *lupus vulgaris* and *erythematosis*, yield to the rays. *Sycosis parasitica* as well as *non-parasitica* and *favus* have been cured after one exposure.

In a case of *sycosis parasitica* which had existed for six years, and had resisted the usual methods of treatment, the author observed a perfect cure after an exposure which lasted seven minutes only.

In a case of *lupus of the inguinal region* the author observed a perfect result. After the sixth exposure inflammation of the lupous area began, and the nodules shelled out, so to say, together with the destroyed tissue. In their place a light red ulcus remained, which bled on the slightest touch, and which did not cicatrize until nine months after the last exposure. In such cases transplantation is generally indicated. It goes without saying that this mode of treatment, while most effective, is very annoying to the patient, whose gratitude to the physician is somewhat restricted on that account, even after perfect recovery.

In some of the cases reported the nodules did not shell out, but shrunk, presenting the appearance of having been painted with varnish.

A great deal can, however, be done to limit the ill consequences of the irradiation treatment of skin diseases, which should not be resorted to unless all other therapeutic measures have been exhausted. Under proper precautions the ill effects of the rays can be avoided. In the first place, the healthy parts in the vicinity of the diseased area should be protected by sheets of staniol. Then the patient's subjective condition should be carefully watched. As soon as there is

a slight burning sensation or itching within the irradiated sphere, further exposures must be stopped.

For therapeutic purposes the tube should be as near to the diseased area as possible, and the time of the first exposure should not be longer than ten minutes. Later on, when no reaction shows, the irradiation may be kept up for from twenty to thirty minutes. In lupus as many as fifty exposures may be necessary until the nodules are destroyed. In obstinate cases exposures may be made daily.

During the intervals the diseased area should be powdered with amylum or dermatol. In the event of relapse, the same treatment must be commenced again.

It is necessary to individualize just the same as in other therapeutic indications. Some individuals show signs of irritation after a few exposures, and others do not react until after frequently repeated and intense irradiations.

At first these remarkable results were explained on the theory of *bactericidal influence of the rays*. But it seems that their effect is of a decidedly electrochemic character, the congestion caused by the irradiation being mainly responsible, just like the artificial hyperemia in tuberculosis. In disturbed nutrition of the skin the inflammatory reaction produced by the rays would set up an alteration in the circulation of the affected spheres.

Bacteriologic experiments have shown that the rays, applied directly after inoculation with anthrax bacilli, as well as with streptococci and staphylococci, had no effect. But pure cultures of cholera, typhus, and diphtheria died after forty-eight minutes' exposure to in-

tense irradiation. It seems that various bacteria react differently according to the quality of the plasma and the degree of the fluid they contain.

Dentistry has also profited considerably by the rays. The relation of the dental roots and their position, the presence or absence of the milk-teeth as well as of the permanent teeth in children, or of an old root, and foreign bodies (fillings, pieces of chisel broken off, for instance, while excavating a carious tooth) can be clearly demonstrated.

Sometimes it is of great forensic importance to determine the age of an infantile corpse by skiagraphing the teeth.

As a rule, it will suffice to place the face portion nearest to the tooth in question on an ordinary Röntgen plate. If fine details are demanded, flexible films may be introduced into the oral cavity, where they will adapt themselves to the contours of the maxilla.

It has been reported that certain types of *neuralgia* are benefited by long exposures.

As stated before, the intensity of the rays increases in proportion to the *height of the vacuum*. If very high vacua are used, even the bones of the hand may become so translucent that they can hardly be distinguished on the plate. Thus it will be easily understood why, for the representation of the bones of the hand, a tube with a low vacuum (so-called mild or soft tube) is to be chosen, while if the rays have to permeate a very thick body, such, for instance, as the pelvis of a fat person, it is the high vacuum tube (hard tube) only that would be capable of throwing so much light through it as to show a well-defined

shade on the plate. From this we learn that, according to the thickness and permeability of the object to be skiagraphed, tubes of low, high, and very high vacuum must be at hand.

Recently, tubes have been constructed by Gundelach which permit of regulation by the diffusion of hydrogen. Into the wall of a tube of this kind a small platinum wire is fused, the end of which protrudes outside to the extent of two inches. If this protruding piece of platinum is heated by a Bunsen burner, the hydrogen of the flame diffuses into the interior of the tube, thus augmenting the intratubal vacuum at will. The heating process must be kept up from one-half to three minutes. The handling of these tubes is troublesome, but their usefulness is great.

Another most important factor that affects the distinctness of a skiagraph is the *length of time of the exposure.* If the most perfect apparatus is used, the hand of an adult can be well represented in less than half a minute, while the forearm requires one minute and a half. The elbow, humerus, and foot, at an average, need from two to two and one-half minutes, and the leg, knee, and thorax, from three to four minutes; while for the shoulder and thigh from four to five, for the skull from five to six, and for the pelvis from six to ten, minutes are generally necessary.

The capacity of a tube is tried best by using it for different lengths of time—viz., for twenty, forty, or sixty seconds—on the same subject, and determining its penetrating power by comparison of the skiagraphs. In children the time of exposure must be lessened, in view of the greater translucency of the bones.

The *distance* of the plate from the tube also deserves

great attention. Different distances give different relations, and the less the distance between plate and tube, the larger the silhouette of the body; but the smaller the silhouette, the more correct the anatomic proportion of the tissues. The more distant the tube is placed, the longer the time of exposure must last. On an average, an equally good skiagraph of the hand is produced when the distance is six inches and when the exposure has lasted half a minute, as when the distance was twelve inches and the exposure a whole minute.

For locating foreign bodies, apparatus have been devised by Hoffmann, Levy-Dorn, Sehrwald, and Angerer. The author has thus far been able to locate foreign bodies in the simple manner described on page 265. The wire letters used for registration (p. 311) can also be used as landmarks; one, for example, being placed above the plate below the wound or scar signifying the entrance of the foreign body, and others at proper intervals on the plate as well as on the surface of the limb. For localization on the skull, wire may be wound around the head, and at various intervals ciphers (compare p. 265) may be spread as landmarks. The same means may be employed on an extremity, where wires may be wound around, and ciphers put on the limb as well as on the plate. The same principles apply to other parts of the body in proper modification.

The objects to be skiagraphed must be in close contact with the photographic plate. As far as their *position* is concerned, it is advisable to take the *forearm* in supination, although this position is by no means the most comfortable one for the patient. The *upper*

arm and the *thigh* can be taken in any position. The *leg* should be skiagraphed while its external surface rests on its support, the knee being bent and the thigh rotated. The *foot*, from the toes up to the upper third of the metatarsus, is best photographed in the direction of the dorsum toward the planta pedis. Further back the first and third cuneiform bones and the scaphoid present an obstacle, so that it is advisable to illuminate the foot on these portions transversely by having the outer surface rest on the plate. By this procedure the isolated shadows of the astragalus, the calcaneum, the os cuboideum, the scaphoid, and the fourth and fifth metatarsal bones can be seen. The *hand* is taken from the dorsum through to the palm. The *knee-joint* rests preferably on the external condyle. The *humero-ulnar joint* should be taken transversely, while the *humero-radial joint* had better be illuminated from the flexor to the extensor side. The *hip-joint* is taken best by turning the patient from his recumbent position inwardly, so that the anterior axis of the thigh forms an angle of from thirty to forty degrees to the underlying plate. The opposite hip is elevated and supported accordingly.

With respect to the *position of the tube*, care should be taken to have the center of the platinum disc exactly above the center of the plate upon which the object rests.

In order to judge a skiagraph thoroughly, the source of the current (whether battery or street), the length of the spark of the induction coil (whether a vibrator or an air-blast is used), the intensity of the tube, the distance of the platinum disc of the tube from the photographic plate, the position of the object, the sort of

plate used, and the time of exposure, must all be mentioned.

For *examination with the fluoroscope* a room must be chosen that can be darkened at will, but the photographic work can be done in any room. The hand and arm can be photographed on a table while the patient is seated on a chair. The other parts of the body may be taken while the patient lies either on a heavy wooden table or on a carpeted floor. (See Fig. 173.)

Absolute rest is the *conditio sine qua non* of a distinct picture. In children and in nervous adults efforts to attain perfect immobilization may fail. The trunk must be supported properly by pillows, while an extremity can be kept quiet by supporting it with sandbags. The patient should, of course, be placed as comfortably as possible, but in some individuals it is utterly impossible to take a skiagraph. Infants should be lulled into sleep, the noise of the battery, if not too strong, sometimes acting like a lullaby. Anesthesia for the purpose of keeping the patient quiet should be resorted to only under the most pressing circumstances.

To sum up, it may be said that the modus operandi in skiagraphy would be about the following:

If the thigh, for instance, should be photographed (see Fig. 173), the patient is laid straight down on the floor. The limb must be denuded and placed on the top of a sensitized plate. The patient is told to be absolutely quiet, for otherwise the whole process is spoiled. The tube must be placed above, in a horizontal position, where it is held by an adjustable stand. The stand used by the author (Fig. 173, *s*)

permits of a wide range of adjustment in the lateral, vertical, and horizontal directions, so that the object can be irradiated from all sides. Its exact position may be verified by dropping a plumb-line from above. Now the positive wire of the coil is connected with the wire-holder of the inclined platinum disc of the tube, while the negative wire is attached to that of the concave aluminium pole. If the lever for the direct current (Fig. 173, *l*) is then turned, the motor begins to run. Thereafter the handle (Fig. 173, *h*) of the switch of the coil is turned, and now a slight spark will pass between the anode (*a*) and the cathode (*c*). By manipulating the rheostat (*r*) the spark is increased gradually until an apple-green light fills the tube, a slightly dark shadow only being noticed below the platinum disc. With the aid of the fluoroscope or of the skiameter, it can be now ascertained whether the fluorescence is intense enough for thorough penetration. The fluoroscope also gives a rough impression of the pathologic conditions.

If all works well, the upper surface of the platinum disc shows a gray glow, while the lower surface produces a light redness. A white-red platinum disc indicates too powerful a current; but this can be diminished by turning the rheostat backward. If, in such an event, the walls of the tube also become very hot, it is advisable to stop the current entirely for at least half a minute. (Compare p. 281.)

The wires leading from the induction coil to the tube must be kept separated from one another in order to avoid shocks. When the exposure is finished, the levers are turned back in the same succession.

If a *static machine* is used, the sliding pole-pieces

are separated about eight inches, the large balls unscrewed from the pole-ends, and the Leyden jars removed. The condensers must then be screwed on, and the square platinum disc is attached to the posi-

Fig. 174.—Complete comminuted intra-articular fracture of the lower end of the radius in a woman of forty years, showing lateral as well as median displacement of fragments (one week after the injury). The negatives of the wire numbers 193 register the plate.

tive pole of the condenser. The length of the spark-gap should be regulated so as to suit the vacuum: it must be long if the tube has a low vacuum, and be short if it has a high one. The machine must be run rapidly, but never backward or with wrong poles.

The plates are then put into a dark place until they are developed, which is done in the usual way, the very simple directions being obtained with the plates when purchased. The plates should be labeled. The author uses small letters and numbers made of copper wire (Fig. 174), which, being placed on an edge of the plate, mark the skiagram properly and permanently, their shades appearing on the plate. If the letter *L* is put at the left and *R* at the right margin of the plate (Fig. 175), the correct position becomes evident at a glance.

Almost all the illustrations in this book were skiagraphed on Carbutt X-ray plates; but the Cramer and Schleussner plates also give very good results. The latter are especially to be recommended for rapid exposures.

If several exposures of the same object must be taken,—as, for instance, in cholelithiasis (see p. 295),—a box of the shape of a drawer must be put underneath, the plates being inserted in place through the open side space without dislodging the object. The plates are always better than the prints, many little details becoming lost during printing.

ERRORS OF SKIAGRAPHY.

As mentioned on page 286, false interpretations of a skiagraphic picture may be caused by the shadows produced by thick layers of bone. In fact, they can hardly be avoided without a thorough knowledge of the *normal* anatomic relations of the bone that produces such shadows.

As the most minute gradation of density is registered,

the importance of being thoroughly acquainted with the anatomic relations of the bones producing the doubtful shadow is evident. The question, then, would be whether the supposed shadow is normal or not. On certain portions of the skeleton the muscles and tendons would naturally cause obscure shadows. The carpus is especially likely to produce such errors in the skiagraph; the tuberositas ossis multanguli majoris, the scaphoid, the hamulus ossis hamati, the os pisiforme, and the eminentiæ carpi volaris radialis and ulnaris double up the thickness of the carpus, thereby causing dark shadows, which might be mistaken for foreign bodies. Similar considerations and similar cautions apply to the other diagnostic opportunities offered by the rays.

If a skiagraph of the human hand, for instance, is taken, the plate will show the least light where the bones rest, while the soft tissues appear opaque. There is also a difference of opacity according to the thickness of the tissues, their blood-supply, and their air-capacity.

The foot, while easily skiagraphed in the direction of the dorsum toward the planta pedis, from the toes up to the upper third of the metatarsus presents an obstacle further backward in the first and third cuneiform bones and the scaphoid, so that it is necessary also to skiagraph the foot on these portions transversely by having the outer surface rest on the support. It is by this procedure only that the isolated shadows of the astragalus, the calcaneum, the os cuboideum, the scaphoid, and the fourth and fifth metatarsal bones can be distinctly outlined, so that false interpretations may be excluded.

In the early Röntgenian era the normal sesamoids were also sometimes incorrectly interpreted.

How important is the knowledge of minute anatomic details, especially of non-pathologic abnormalities, will be evident from the fact that the *os intermedium cruris* (os trigonum tarsi) has been mistaken for a fragment severed from the astragalus. This bone is a typical part of the tarsus of all mammalia, and its frequency is estimated at from seven to eight per cent.

Shepherd,* who mistook this bone for a fractured fragment, says: "The fact that this fracture is not mentioned in any of the text-books of surgery or in special treatises on fractures would easily be accounted for by its only being discovered by dissection; it causes no deformity, and the symptoms it would give rise to during life would probably be obscure." The same author tried to produce this fracture artificially on the cadaver, but "in every case," he says, "where this manœuver was performed I failed, even when the greatest force was used, to break off the little process of bone mentioned above."

Pfitzner† regards the os trigonum tarsi as an integral part of the posterior process of the astragalus in the adult, which is analogous to the os intermedium antibrachii.

The practical significance of this bone is evident from a case described by Wilmans,‡ which is also highly interesting from a medicolegal standpoint:

* "A Hitherto Undescribed Fracture of the Astragalus," "Journal of Anatomy and Physiology," October, 1882.

† "Beiträge zur Kenntniss des menschlichen Extremitaätenskelets," "Morphologische Arbeiten," 1896, 2 tes Heft.

‡ "Fortschritte auf dem Gebiete der Röntgenstrahlen," Band II, Heft 3.

A laborer claimed that he was injured by an iron bar on January 20, 1897, but was able to work during the whole day. On the following day he called on Dr. Wilmans, complaining of intense pain at his internal malleolus. He limped and asserted his inability to work. Wilmans found a slight swelling below the right internal malleolus. Ecchymosis of the skin being absent, the swelling was attributed to the presence of a considerable degree of talipes, from which the laborer suffered at the same time. The leg was elevated and fomentations were applied for several days. The laborer still complaining of great pain, it was decided to transfer him to a hospital for observation. When discharged, after several weeks of treatment, the laborer made an effort to resume work, but at once declared that he was unable to keep it up. He was therefore admitted to another hospital, where he repeated this manœuver several times during a period of six months. Finally he claimed damages for having been crippled by the injury sustained on January 20, 1897, but in view of the negative objective condition found by Dr. Wilmans, the society decided not to grant any claims. The consequence was that the laborer was transferred to the surgical division of a third hospital for further observation. There he complained that he had continuous pains below the right external malleolus, even while in the recumbent position. The pain increased while walking or sitting. Stepping on the right heel he also declared to be impossible. By distracting his attention, however, it was noticed that he could stand well on his heel, and he would undoubtedly have been declared a malingerer, had not the Röntgen rays come to his rescue, at least temporarily. A skia-

graph showed a bone-fragment at the junction of the astragalus with the posterior surface of the calcaneum. On the strength of this skiagraphic "proof" Dr. Wilmans, although still mistrusting, was forced to modify his original opinion, and certified that the patient suffered from "*fracture of the astragalus, in consequence of which he was damaged for life.*" The laborer therefore received an annuity of thirty per cent., in proportion to the estimated curtailing of his wages.

Soon afterward the laborer was discovered by Dr. Wilmans carrying a heavy weight without any apparent pain, while formerly he had claimed to be unable to walk without a cane or a crutch. Dr. Wilmans insisted upon a second irradiation, this time also skiagraphing the uninjured left foot. The skiagraph showed the "severed bone fragment," which had first been regarded as a sesamoid of the musculus flexor longus hallucis, but which was now recognized as a *normal os intermedium cruris*. The society, of course, refused the annuity, and the German Supreme Assurance Court, to which the laborer had appealed, not only sustained the verdict of the society, but also decided that the laborer must return the annuity which he had unjustifiably enjoyed for eighteen months.

The significance of a skiagraph for the purpose of *estimating the degree of functional disability*, while great in general, is not always conclusive. A skiagraph may show a considerable degree of bony deformity after a fracture (compare Fig. 113), and still the function may hardly be disturbed at all. Skiagraphic test has shown that, as a whole, even our best functional results show by no means an ideal union, like figure 32, for instance. An unscrupulous patient

who secures possession of a skiagraph of his own case, which shows considerable deformity, may, although there is no functional disturbance, strongly appeal to a jury on the strength of his skiagraph, if he succeeds in simulating great impairment. On the other hand, there may be but little evidence of bone-injury on the skiagraph, but there may be severe impairment of function on account of the injury to the soft tissues (circulatory, trophic, or inflammatory disturbances), which can be represented only faintly, if at all. This shows the *necessity of considering all the other clinical symptoms in connection with the skiagraph.*

While it is easy, even for a layman, to understand the significance of most of the skiagraphs illustrated in this book, there are injuries the correct interpretation of which presupposes, besides thorough anatomic knowledge, the greatest care and a vast amount of experience as to the different modes of delineation in various projection-planes.

The greatest diagnostic difficulties are offered by the joints. The more complicated a joint is, the more complicated the skiagraphs of its various positions will naturally appear. It is especially the elbow-joint and hip-joint which are kept in view. First of all, the interpretation of the displacement caused by supracondylar fracture of the humerus, and the deformities resulting from it later on, may tax the power of discrimination considerably.

The older the fracture, the less conspicuous the fracture-line will appear, since it will be more or less overshadowed by the callus. In old fractures the line can not be represented as such, and it is only in case of union in a displaced position that its features

could be guessed. In the case illustrated by figure 129, for instance, a second skiagraph was taken three

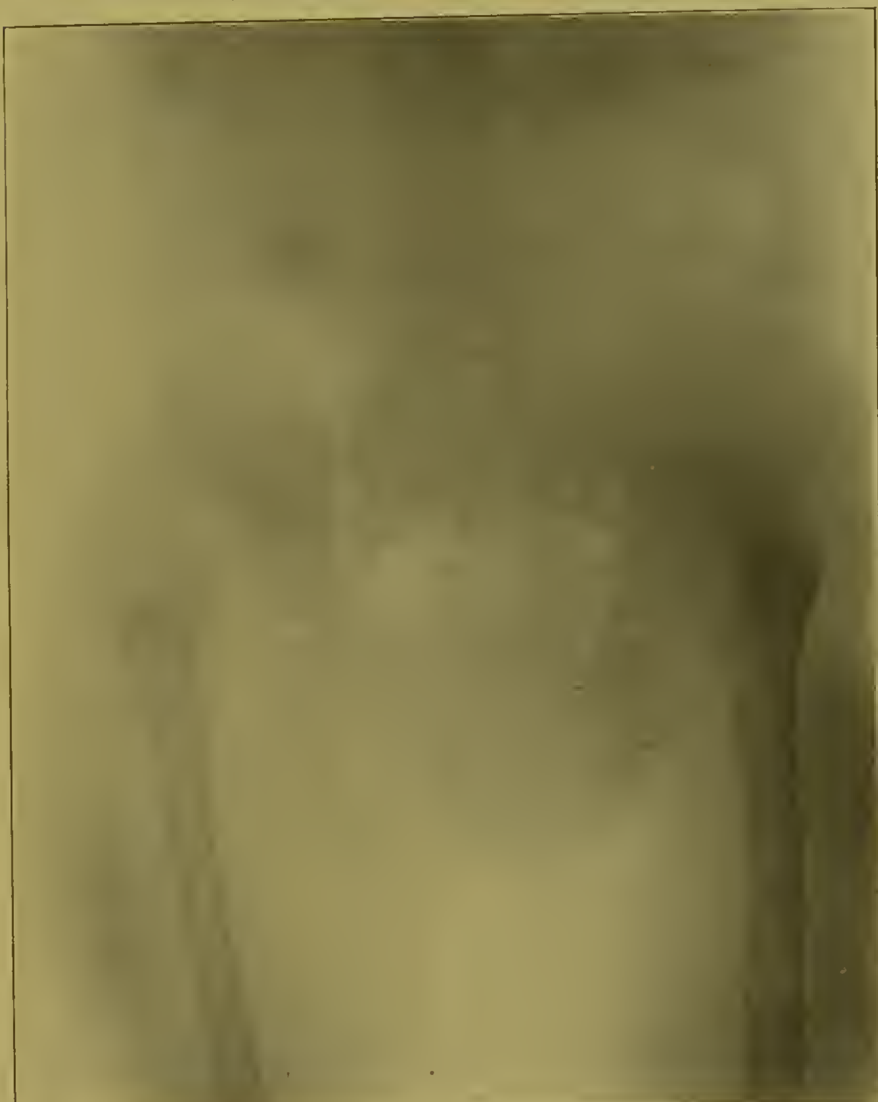

Fig. 175.—Congenital dislocation of both hips in a girl of seven years. The non-ossified epiphyses of the heads of the femur must not be mistaken for fracture fragments.

years afterward, which showed essentially the same features as figure 129, which had been taken four

weeks after the injury. (Compare also Figs. 128, 130, and 141.)

In the case of entire *absence of displacement* it is only a very distinct skiagraph that shows the line clearly. (Compare Fig. 138.) It is natural that in such cases there is no skiagraphic evidence after recovery —that is, in from four to ten weeks, according to the type of fracture.

Should a court, for instance, doubt, in such an event, that there had been a fracture, a skiagraph taken after such a period might show a negative result, although there surely was a fracture. In the case illustrated by figure 109 the very distinct skiagraph, taken only two months after the injury, showed no signs of a fracture.

In the case illustrated by figure 32, where no displacement existed, there was only a faint fracture-line, but the presence of the callus left no doubt as to the previous existence of a fracture. (Also compare Fig. 175.)

On the other hand, *callus formation* may be so abundant (Figs. 87 and 88) that, in spite of the absence of displacement, the fullest evidence of fracture may still be furnished after months.

The *intra-articular fracture types* offer the greatest diagnostic difficulties, inasmuch as the fracture-line is also often obscured by the callus formation. (Compare Figs. 46 and 52.) If, however, a skiagraph of the other joint is made at the same time, in the same position, and in the same projection, the various delineations of the shadows will be correctly understood and interpreted.

A normal skeleton should also always be compared

on the skiagraph. It should particularly be remembered that certain pathologic conditions—such as rachitis, for instance—influence the outlines of the bones and may deceptively be supposed to represent a portion of an injury. In such an event the skiagram of the fellow-extremity will set matters right. (Compare case described on p. 314.)

In very young children the eminentia capitata (Fig. 177) appears as if entirely severed from the humerus, although the relations are normal. The explanation of this important phenomenon is that the epiphyseal tissues are not sufficiently ossified to produce a shadow on the plate. If these points are not thoroughly considered, a displaced fracture-fragment might be erroneously diagnosticated.

As referred to on page 74, union between the *epiphysis* and the diaphysis of the *head of the humerus* is not perfect before the twentieth year. (Compare Fig. 32.) The lower epiphysis of the humerus consists of four nuclei, which do not ossify before from the eighth to the seventeenth year. (See Figs. 176, 177.)

The epiphyses of the *trochlea* as well as of the olecranon do not ossify before between the seventh and the twelfth years, which explains why an osseous nucleus that is still connected with its neighboring epiphyseal nuclei and the diaphysis by cartilaginous tissue appears as an isolated piece of bone which might erroneously be taken for a fragment. (Compare Fig. 176.)

The *acromio-clavicular junction* sometimes shows in the skiagraph a hiatus of the width of a finger, so that a diastasis of the joint might be assumed. (See Figs. 16 and 21.) But since our knowledge on this new sub-

ject has increased, we know that this apparent diastasis is by no means pathologic, and that there is a normal gap between the osseous ends of the acromion and the acromial end of the clavicle.

The upper *epiphysis* and the diaphysis of the *radius* (see Figs. 46, 49) unite between the seventeenth and the eighteenth year, and its lower epiphysis and dia-

Fig. 176.—Elbow-joint in a boy of ten years, four hours after backward dislocation of radius and ulna had occurred and two hours after reduction. The non-ossified connection of the lower epiphysis of the humerus appears like a fracture-line, but the relations are perfectly normal with the exception of the dark shades in the soft tissues, which represent the bloody effusions caused by the injury.

physis join in the twentieth year. (Compare Figs. 76, 87.) During the early Röntgenian era the translucent space above the epiphyseal cartilage in children was erroneously taken for a fracture-line. (Fig. 73.)

The *head* of the *femur* unites with the diaphysis at the eighteenth or nineteenth year (compare Fig. 109), and the lower epiphysis follows after the twentieth year. (Compare Figs. 118 *a* and 140.)

The upper epiphysis of the *tibia* unites with the dia-

physis in the twentieth or twenty-second year (Figs. 118 *a* and 140), while the lower tibial epiphysis unites with the diaphysis between the eighteenth and the nineteenth year. (Compare Fig. 137 and *Frontispiece.*)

As to the different periods of ossification of the pelvis and the normal translucent spaces in children, compare figures 109, 113, and 175.

For the thorough interpretation of skiagraphs in children, it is important to know that at birth the diaphyses of the *radius*, the *ulna*, the *metacarpal bones*, and the *phalanges* are ossified, while their epiphyses, as well as the whole carpus, are still cartilaginous. It is not before the seventh year that an osseous nucleus shows at the lower epiphysis of the ulna. Union with the diaphysis sometimes begins with the twelfth year, but, as a rule, not before the fifteenth. Even then a small epiphyseal disc remains, which does not disappear before the seventeenth year in the female, and not before the nineteenth year in the male.

As to the osseous nucleus of the lower end of the radius, compare page 74.

The osseous nuclei of the *carpus* show at different periods—viz., at the os capitatum, at the fourth month; at the hamatum, at the fifth month; while the triquetrum shows its nucleus between the second and the third year, the lunatum between the third and the fifth, the naviculare between the fifth and the seventh, the trapezium and the trapezoid between the sixth and the seventh year, and the os pisiforme between the eleventh and the fifteenth year.

After five years the capitatum, hamatum, and triquetrum have assumed their regular shapes, while the

others, with the exception of the pisiforme, are perfectly developed at the twelfth year.

The osseous nuclei of the epiphyses of the *metacarpal* bones show at the second year, their synostosis with the diaphysis taking place between the twelfth and the seventeenth year in the female, and at the age of nineteen in the male. The epiphyseal nuclei of the *phalanges* are ossified between the fourth and the fifth year, their synostosis with the diaphysis taking place at the same age as that of the metacarpal bones (from the twelfth to the seventeenth year in the female, and between the sixteenth and the nineteenth year in the male).

Regarding the *elbow-joint*, it must be considered that an osseous nucleus appears at the interior of the capitulum humeri between the second and the third year, another one in the internal epicondyle at the fifth year, a third in the trochlea between the eleventh and the twelfth year, and soon afterward a fourth in the external epicondyle. The nucleus of the internal epicondyle unites with the diaphysis between the sixteenth and the twentieth year; but the other three nuclei form a synostosis among themselves at the seventeenth year, and then form the uniform osseous epiphysis, which completes its synostosis with the diaphysis at about the twentieth year. (Compare Figs. 176 and 177.)

In the *capitulum radii* an osseous nucleus appears between the fifth and the seventh year, and in the *olecranon* between the sixth and the eighteenth year, both uniting with the diaphysis between the twentieth and the twenty-fifth and between the sixteenth and the twentieth year.

Regarding the *knee-joint*, it must be considered that the lower femoral epiphysis contains an osseous nucleus at birth, while the nucleus in the tibial epiphysis shows shortly afterward. At the fourth year both these epiphyses have completed their development, but they do not unite with the diaphysis before the fifteenth year. The anatomic text-books say that union takes place between the seventeenth and the

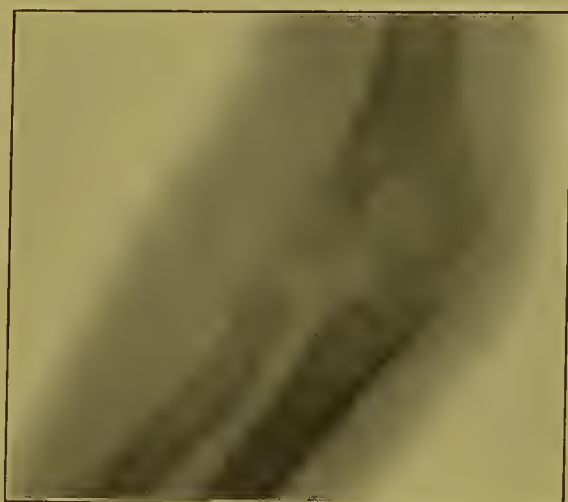

Fig. 177.—Showing fracture of internal condyle, but normal eminentia capitata, the latter appearing severed from the humerus, in a boy of nine years. The perfectly normal radial epiphysis also appears severed.

twenty-fourth year, but skiagraphic experience points to an average period of only sixteen.

The osseous epiphyseal nucleus of the *fibula* appears between the second and the fifth year, and unites with the diaphysis between the eighteenth and the twenty-fifth year; but skiagraphy dates this period earlier—viz., the fifteenth year. The osseous nucleus in the tibial spine appears between the eighth and the tenth year; the epiphyseal line disappears between it and the diaphysis at the fifteenth year.

As to the bones of the *foot*, it may be said that the lower epiphyses of the tibia and the fibula show their osseous nuclei in the first and second years, and unite with the diaphysis between the eighteenth and the twenty-fifth year ; according to skiagraphs, as early as before the eighteenth year. The osseous nucleus of the astragalus and calcaneum appears *intra utero*, that of the cuboid shortly before or after birth, that of the cuneiformia between the first and the fifth year, and that of the os naviculare from the first to the fifth year. The osseous nuclei of the metatarsal bones and of the phalanges appear from the second to the tenth year, and unite with the diaphyses between the sixteenth and the twenty-second year.

In joint fractures occurring in childhood it is necessary, therefore, to take at least two skiagraphs in different projection-planes and to compare them thoroughly with the normal fellow. In a case of fracture of the femoral head, for instance, the deformity had appeared three times as large as it actually was, on account of inappropriate projection. The degree of shortening of the limb was overestimated accordingly. This shows the necessity of considering the other clinical symptoms and data in connection with the skiagraph.

In fractures of childhood it should also be remembered that the process of ossification is influenced by various affections of the bone, as, for instance, in *rickets*.

How important the question of *projection* is becomes evident when we consider that grave errors may sometimes occur even if all the preliminary conditions required for a thorough understanding of the case seem to be fulfilled. This will appear from the

following experience, which has probably not been paralleled in the literature of this subject:

A boy four years of age, while playing on the street, fell against an iron bar. Being unable to rise again, he was taken up and carried to St. Mark's Hospital, where in the first instance moderate pain was noted besides the functional disturbance. There was neither any difference in level or any other deformity, nor any shortening or the typical equinus position. A photograph taken two days after the injury only showed a very moderate and uniform swelling of the leg.* Abnormal mobility and crepitus, in accordance, could be produced only by very rough manipulations.

On the day following the injury two skiagraphs were made in different positions; one of them (Fig. 137) in the dorsal and the other (Fig. 139, A) in the lateral position. To my surprise, figure 137—which had been skiagraphed by a direct irradiation, the center of the platinum disc of the tube being perpendicular to the anterior surface of the leg—did not show the slightest indication of a fracture, while figure 139, *A* (also compare *Frontispiece*), which represents the leg irradiated from the outer aspect of the tibia, shows a marked fracture-line.

The fracture presented the typical oblique type in the middle of the tibia, the fracture-line running from below anteriorly to above posteriorly, the upper, tapering fragment overlapping the lower end. No sideward displacement having been present, it can be understood why the rays, reaching the long axis of the tibia in a vertical direction, do not show the fracture-line.

* Photograph published in "New York Medical Journal," January 6, 1900.

A very slight change in the position, where the inclination toward the fibular direction amounts to less than one millimeter, brought out the fracture distinctly.

Now, if I had, as is the custom in general, taken a skiagraph in the anteroposterior direction only, and if the manipulations made during the first examination were carried out as gently as they properly should be, the fracture might have been overlooked entirely. And if, in view of the local pain and tenderness, the swelling, and the functional disturbance, the possibility of a fracture would have been seriously considered, the skiagraph (Fig. 137) might have silenced the uneasy conscience.

This experience teaches the necessity of adopting the principle of always taking at least two skiagraphs in two different positions in all cases of suspected fracture.

The medicolegal aspects of a case of this kind need no further comment.

In taking skiagraphs of foreign bodies it must be considered that their size varies according to the distance from the tube. (Compare p. 305.) In oblong bodies great errors as to their extent may be committed. The author once was very much surprised in a case where a needle-fragment had entered the palm of the hand in a perpendicular direction. The plate, while indicating the presence of the needle distinctly, created the impression that the fragment was only about two millimeters in length. When extracted it was found to be more than an inch long, the rays having reached the hand in a perpendicular direction, so that the circumference of the fragment was reproduced rather than its length. A side view, of course, would have cleared up the error at once.

Misinterpretations have also arisen from unavoidable mechanical and chemic defects, causing markings in the photographic plate, the significance of which must be well known to the skiagraphic interpreter.

Blemishes may be produced by spots caused by pus from wounds or by perspiration.

In the location of foreign bodies, especially in the skull, many errors were and are still committed. As to their avoidance, compare pages 265 and 306.

In drawing conclusions from skiagraphs it should especially not be lost sight of that a skiagraph is by no means a photograph of an object, but a silhouette —that is, a photograph of its shadow.

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